Artificial ventilation of the lungs for emergencies

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Abstract—The necessity for extraordinary ventilatory support may appear in different places all over the world in cases of a massive disaster (industrial or natural), connected with gas poisoning on a huge scale. Hospitals equipped with limited number of respirators, adequate for peacetime activity, are not able to meet suddenly multiplied requirements for ventilatory support. This paper describes a preliminary study to develop a convenient, reliable method of performing artificial ventilation of at least two patient by means of only one ventilator. We developed a unique, new control system (patent pending) which, when placed between a respirator and endotracheal tubes of the patients, divides the total tidal volume between the patients’ lungs and controls pressures at their airways. A special arrangement of valves in the control system enables us to separate inspiratory and expiratory paths for each patient and to avoid cross-infection. The model study performed, according to ISO standards, on mechanical test lungs has shown that the proposed control system enables us to adjust ventilatory parameters at desired values, when lung compliance or respiratory airway resistance differ. The proposed one-source artificial ventilation is a simple solution to provide ventilatory support when the number of patients is greater than the number of respirators that are available.

Key words: Apparatus and instruments; mechanical ventilation; emergency positive pressure ventilation; model studies.

1. INTRODUCTION

Over the last decade the risk of gas poisoning on a large scale has increased. We were very close to such events during Persian Gulf war in 1991 or, more recently, during the terrorist gas attack on the Tokyo underground. The problem of hospitals prepared to meet extremely high demands for ventilatory support systems in a short time is really significant. Intensive Care Units are prepared to deliver artificial ventilation of the lungs to the number of patients that are easily defined for peaceful time operations. However, in unpredictable emergency situations, which may also concern natural or industrial disasters on a huge scale, the number of respirators may be much smaller than the number of patients that immediately require ventilatory support.
Intensive care respirators are expensive instruments, so their surplus is very much limited. Another solution is to provide artificial ventilation to at least two patients by means of one respirator. The aim of our studies was to examine if such a solution is potentially possible. We propose to insert a simple, inexpensive control unit between the respirator and two patient’s lungs to control their tidal volumes and airway pressures. Selective positive end-expiratory pressure (PEEP) for each patient is also maintained, as PEEP is often applied to improve blood oxygenation [1] and lung mechanics [2]. We assumed that our ventilatory system will serve gas paralyzed patients but with basically healthy lungs, so ventilatory frequency and inspiratory/expiratory ratio can be the same for two patients ventilated by one respirator.

Ventilatory circuits for these patients are isolated to overcome the risk of cross-infection.

2. METHOD

The idea of automatically ventilating at least two patients by means of only one respirator is presented in Fig. 1. A respirator does not deliver an air/oxygen mixture to patient’s lungs directly but by means of a control system. Such ventilatory variables as frequency \( (f) \), tidal volume \( (TV) \) and inspiratory/expiratory time ratio \( (T_i/T_e) \) are adjusted on the respirator. The division of tidal volume between two patients \( (V_1/V_2) \) is adjusted on the control system, which also monitors expired volume and airway pressure for each patient. The division of tidal volume may be realized in many different ways. As our aim was to build a simple, inexpensive control system for this particular application, we decided to use a threshold pressure valve (Fig. 2) or differential pneumatic resistance (Fig. 3) to divide tidal volume between two patients. As can be seen from Fig. 2, during the inspiratory time the mixture of air/oxygen from the inspiratory port (IP) of the respirator is delivered to the patient’s lungs by two separated, parallel lines, through two one-way pneumatic valves.

During the expiratory time, as the IP is closed and the expiratory port (EP) of the respirator is open, the patient’s lungs are deflated when expiratory flows are directed by two other parallel lines and two one-way valves to the respirator. Airway pressure and expired volume for each patient are continuously measured. Automatically open and closed IP and EP of the respirator and four one-way valves of the control

![Figure 1. The concept of automatic ventilation of two patients by means of only one respirator.](image-url)