LUNG SIMULATOR USED TO STUDY THE RESPIRATORY MECHANICS EFFECT UPON THE INTRAPULMONARY PRESSURE

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ABSTRACT
Changes in respiratory mechanics can affect the efficiency of artificial lung ventilation substantially. Therefore, experimental measurement was made to study intrapulmonary pressure during changed mechanical properties of the respiratory system for spontaneous breathing and for use of conventional ventilation and high-frequency ventilation. Lung simulator ASL5000 was used to study interaction between the pulmonary mechanics and intrapulmonary conditions. Ventilators Veolar from the Hamilton company and 3100B from Sensormedics company were used while studying conventional ventilation and high-frequency ventilation. It was possible to maintain constant tidal volume during conventional ventilation for increased airway resistance with small increase in dynamic pressure. On the other hand, the dynamic pressure was substantially increased during high-frequency ventilation when the airway resistance was increased. The respiratory mechanics has a direct effect on the intrapulmonary conditions and it affects the efficiency of different ventilatory regimens. Conventional ventilation seems to be gentler to the respiratory system while ventilating lung with increased airway resistance.

KEY WORDS
Artificial lung ventilation, lung simulator, airway resistance, intrapulmonary conditions.

1. Introduction
Inversed pressure is used during artificial lung ventilation (ALV) in many cases of ventilatory regimens compared with pressures during spontaneous breathing. Increased alveolar pressure can induce damage of the lung tissue and decrease the patient’s benefit from use of ALV. The aim of the study was to observe the changes in intrapulmonary pressures during conventional ventilation (CV) and high-frequency ventilation (HFV) for different changes of the respiratory mechanics. Clinical experiences show that efficiency of CV and HFV is dependent upon respiratory mechanics [1, 2, 3].

2. Body of Paper
Ventilator Veolar from the Hamilton Medical company, high-frequency ventilator 3100B from the Sensormedics company and lung simulator ASL5000 from Ingmar Medical company were used for experimental measurement. Veolar ventilator was used to ventilate the lung when studying use of CV. Experiment was made for normal and increased airway resistance. Ventilation with constant flow during inspirium was set while studying CV. Breathing frequency was 12 breath/min, tidal volume was Vt = 0.5 l and ratio of inspirium and expirium was 40:60. The ventilator maintained constant minute ventilation and the effect of increased airway resistance upon CV efficiency was studied.

High-frequency oscillatory ventilation is pressure controlled ventilatory regimen. Mean airway pressure (Paw = 20 cmH2O) and dynamic pressure (∆P = 15 cmH2O) were set during HFV ventilation. Tidal volume is proportional to the dynamic pressure. The ratio of inspirium and expirium was 40:60. The effect of the increased airway resistance upon the intrapulmonary pressures during CV can be seen in Fig. 1 for normal and increased airway resistance. Resistance was two times and three times increased contrary to typical value during CV ventilation. Mean and peak pressures are increased in cases of increased airway resistance but the changes in both: proximal and peak pressures are relatively small compared with increase of airway resistance. There is an increase in peak and proximal pressure about 10 % for twice increased airway resistance.

The HFV is pressure controlled kind of ALV and therefore the pressures are constant with increased airway resistance during whole measurement. Effect of increased airway resistance upon the intrapulmonary conditions during HFV is depicted in Fig. 2. Increased airway resistance directly affects the tidal volume because of constant pressure. It can be seen that decrease of tidal volume is consistent with airway resistance increase. Tidal volume is approximately two times decreased for twice increased airway resistance.
Fig. 1: Mean and peak pressures in lung simulator for normal and two times and three times increased airway resistance.

Fig. 2: Peak pressure, tidal volume, mean pressure and work of ventilator during HFV for normal, two times and three times increased airway resistance.
3. Conclusion

The increase of ventilatory pressure increases the risk of injury of patient's respiratory system. Protective ventilatory regimens are used in the clinical practice to minimize the risk of barotrauma even if optimal partial pressure of the oxygen in the blood is not reached during ALV.

The aim of the study was to realize the measurement to confirm the effects observed in the clinical practice. The hypothesis was that the changes in the pulmonary mechanics affects the intrapulmonary parameters during ALV and consequently the efficiency of ALV can be affected. It was shown that efficiency of HFV is strongly dependent on the respiratory mechanics while treating acute respiratory distress syndrome [4].

It was possible to maintain constant minute volume during twice increased airway resistance with small pressure increase (about 10 %). Almost twice increased pressure must be used to maintain constant tidal volume when simulating use of HFV.

Studying relationship between the intrapulmonary pressure and airway resistance shows that CV is technique that is capable to ventilate the patient with increased airway resistance with minimal increase of dynamic pressure amplitude. It suggests that CV is gentler to the respiratory system compared with HFV when ventilating respiratory system with increased airway resistance. Increased airway resistance is one of the main symptoms of chronic obstructive pulmonary disease (COPD).

The results of experiment are in concordance with simulation conducted using a mathematical model of the respiratory system implemented in Matlab [5]. Simulations conducted on the model suggest that CV is more suitable technique for cases of increased airway resistance whereas HFV is more suitable for decreased alveolar compliance.

Use of lung simulator allows studying the interaction between the mechanical properties of the respiratory system and various regimens of ALV. Simulations also show that use of lung simulators can be beneficial for the clinical practice. It can be used to train the medical staff working with ventilators and it also enables to gain experiences.

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References


