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# CONTENT

SECTION 23.

MEDICAL SCIENCES AND PUBLIC HEALTH

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# COMPARISON OF THE EFFECT OF CONTROLLED MECHANICAL VENTILATION MODES IN TERMS OF VOLUME AND PRESSURE IN PATIENTS WITH PULMONARY CONTUSION WITH SIGNS OF ACUTE RESPIRATORY DISTRESS SYNDROME

**Background.** Pulmonary contusion is one of the most frequent injuries in blunt chest injuries. In various studies, the prevalence of pulmonary contusion in blunt thoracic trauma ranges from 25 to 75% [1]. Pulmonary contusion is result when chest trauma in direct or indirect damage to the lung parenchyma, resulting in edema or alveolar hematoma and loss of physiological lung structure and function. This type of damage leads to a decrease in gas exchange, a violation of the ratio between ventilation and perfusion in the direction of decrease, leads to an increase in the resistance of the pulmonary vessels and a decrease in lung compliance within 24 hours. In patients with severe trauma, the inflammatory response leads to acute respiratory distress syndrome (ARDS) [2]. The main component of specialized care for patients with ARDS in the intensive care unit is respiratory support with the creation of constant positive pressure in the airways of patients to open the alveoli, improve ventilation-perfusion ratios and reduce shunting in the pulmonary circulation. Patients also need to enrich the inhaled gas mixture with oxygen [3]. There are two main directions of invasive respiratory support: 1) with the regulation of ventilation according to the required volume of the injected air-oxygen mixture; 2) with the regulation of ventilation according to the level of pressure in the respiratory tract, which reduces the risk of developing lung barotrauma. So far, there has not been a clear advantage of using one or the other method for patient survival [4]. We also set as the purpose of our work a comparative study of the effectiveness of two modes of lung ventilation in patients with thoracic injury on the background of a pulmonary contusion and ARDS.

**Materials and methods.** We analyzed the results of intensive care in 40 patients with thoracic trauma who had signs of pulmonary contusion and ARDS. All patients with thoracic trauma we examined were men. Thirty-six patients (90%) had injured in a traffic accident. Among them were both drivers and passengers of vehicles, and pedestrians. Two patients had injured when falling from a great height. Two patients had physically abused. The specialists of our clinics established the diagnosis of pulmonary contusion: 1) on the basis of the presence of data on the mechanism of injury; 2) on the presence of complaints of chest pain and shortness of breath in patients; 3) on the basis of the results of a thorough examination of the chest wall and auscultation of the lungs; 4) on the basis of chest X-ray data, which were carried out in a straight line projection; 5) based on a pulse oxymetry study when patients breathe air and an air-oxygen mixture. We performed invasive respiratory support in 20 patients (group 1) using the controlled mandatory ventilation mode with volume control (VCV); and another 20 patients (group 2) underwent controlled forced ventilation with pressure control (PCV). We set ventilation parameters for patients under conditions of intravenous anesthesia with ketamine and diazepam and muscle relaxation with atracurium. When using ventilation mode VCV, we performed invasive controlled ventilation using a tidal volume of 6 ml /predicted body weight (PBW). The PMB calculation was as follows:

*For males: PBW (kg) = 50 + 0.91 * (height [cm] - 152.4)* (1) For patients in whom we performed PCV, we limited the peak airway pressure to 30 cm $H_2O$. Positive end-expiratory pressure (PEEP) for both groups of patients was as follows. PEEP for patients with signs of ARDS grade one severity, we set at the level of 9-11 cm $H_2O$, and for patients with signs of ARDS grade two at the level of 12-14 cm $H_2O$. We selected the level of driving pressure so that under conditions of complete muscle relaxation by atracurium, the value of the tidal volume approached the value of 6 ml/kg PBW. We started ventilation with PEEP at 5-6 cm $H_2O$ and then increased the PEEP to the target value. For patients in whom the PCV ventilation mode used, the driving pressure was 10-12 cm $H_2O$. Thus, the plateau pressure was in the range of 20-26 cm $H_2O$. We have presented here the characteristics of both groups of patients in Table 1.

*Table 1*

**Main characteristics of two compared groups of patients with signs of pulmonary contusion & ARDS who received two different methods of invasive respiratory support (M±SD; n)**

| Indicator / Group | Group VCV respiratory support | Group PCV respiratory support | p |
|---|---|---|---|
| Number of patients, n | 20 | 20 | 1 |
| Men/women, n/n | 20/0 | 20/0 | 1 |
| Age of patients, years | 45.75±9.31 | 41.80±9.17 | 0.18 |
| Body mass index, kg/m$^2$ | 25.60±1.32 | 25.68±1.53 | 0.86 |
| Body surface area, m$^2$ | 2.00±0.05 | 1.99±0.05 | 0.93 |
| Assessment by AIS, points | 3.95±0.60 | 4.15±0.59 | 0.30 |
| Evaluation by ISS, points | 26.25±4.06 | 25.35±3,77 | 0.47 |
| Evaluation by TTSS, points | 10.00±1.62 | 9.30±1.42 | 0.15 |
| Breathing rate, 1/min. | 22.20±1.28 | 21.30±1.13 | 0.048 |
| Pulse rate, 1/min. | 110.70±3.39 | 110.85±2.50 | 0.87 |
| Systolic blood pressure, mm Hg | 118.75±4.25 | 118.75±9.16 | 1 |
| Diastolic blood pressure, mm Hg | 73.25±4.67 | 73.00±5.23 | 0.87 |
| Mean arterial pressure, mm Hg | 88.42±3.92 | 88.25±5.71 | 0.52 |
| Need for vasopressors, n | 0 | 0 | 1 |
| Perfusion index, % | 2.15±0.29 | 2.18±0.33 | 0.80 |
| $SpO_2$% when breathing air, % | 84.30±1.84 | 85.25±1.65 | 0.094 |
| $SpO_2$% when breathing with 60% oxygen (not with a tight mask), % | 93.15±1.09 | 93.65±0.99 | 0.14 |
| ARDS grade 1 severity, n | 15 | 15 | 1 |
| ARDS grade 2 severity, n | 5 | 5 | 1 |

| | | | |
|---|---|---|---|
| ARDS grade 3 severity, n | 0 | 0 | 1 |
| Hemoglobin concentration in blood, g/l | 127.70±11.02 | 131.80±10.13 | 0.23 |
| Unilateral hemopneumothorax, n | 16 | 16 | 1 |
| Bilateral hemopneumothorax, n | 4 | 4 | 1 |
| Chest flotation, n | 0 | 0 | 1 |
| Myocardial contusion, n | 0 | 0 | 1 |

We assessed the severity of the injury using Abbreviated Injury Scale (AIS) & Injury Severity Score (ISS). We used these scales to establish the fact of the presence of polytrauma. All patients had signs of polytrauma. We assessed the severity of the thoracic injury using Thoracic Trauma Severity Score (TTSS). The main criterion for determining the severity of ARDS was the value of the oxygenation index – the relationship between the oxygen tension in arterial blood and the size of the inhaled oxygen fraction per unit volume of the gas mixture that the patient breathes – $PaO_2/FiO_2$.

The target point for the effect of oxygenation with both respiratory support methods was to achieve a $SpO_2$ of 96%, which usually corresponds to the lower limit of normal arterial blood oxygen tension ($PaO_2$) of 80 mm Hg. We solved this problem by gradually increasing the fraction of exhaled oxygen ($FiO_2$). The value of this indicator simultaneously served as a marker of the effectiveness of improving the relationship between ventilation and perfusion. The frequency of artificial breaths varied in patients of both groups within 19-24 per minute. For both modes of respiratory support, we chose a ratio of the duration of inhalation to the duration of exhalation equal to 1:2. Another task was to maintain the carbon dioxide tension ($PaCO_2$) in the arterial blood at the level of 45-49 mm Hg. After all, moderate hypercapnia, not exceeding a $PaCO_2$ value of 50 mm Hg, has an anti-inflammatory effect on lung tissue [3]. Indicators of pulse rate, blood pressure, oxygen saturation of peripheral arterial blood and perfusion index we monitored. We also performed capnometry. Capnometry readings presented as $P_ECO_2$.

The results of the study were processed using recognized methods of modern mathematical statistics and presented in the form of M±SD (mean average statistical value ± standard deviation). To determine the reliability of the difference in results, samples we checked for normality of distribution. The Shapiro-Wilk test and the chi-square test we used to test the distribution for normality. In the presence of correspondence of both samples that we compared to the "classical" normal Gaussian distribution, the parametric criterion of reliability of the Student (Student, t-test) we used. If at least one of the samples did not correspond to a normal distribution, the non-parametric Wilcoxon test (Wilcoxon W-test) used for comparisons between two groups. When comparing frequency indicators, the Pearson chi-square test we used. The presence of reliable differences was established when the value of the probability of coincidence of events (results) p, which is less than 0.05.

**Research results and their discussion.** The advantages of VCV include the provision of a guaranteed respiratory volume during artificial pulmonary ventilation, which in turn provides a more stable minute volume of ventilation; at the same time, the minute volume of ventilation remains stable in the range of changes in lung characteristics (lung compliance and airway resistance). The initial flow rate in VCV is lower than in pressure-controlled (PCV) modes, avoiding the early peak airway pressure associated with high resistance. The disadvantages of VCV mode are that the mean airway pressure will be lower than with pressure-controlled ventilation. A smaller number of alveoli will be involved in ventilation, especially in those parts of the lungs in which there is low compliance due to edema, inflammation, hemorrhage or other reasons. If a leak is present, the mean airway pressure may not be stable, and insufficient flow may cause the patient become desynchronized with the ventilator. The advantages of PCV are the ability to create a higher mean airway pressure and increase the duration of alveolar recruitment. In the conditions of PCV, a higher average pressure in the inspiratory tract combined with a decrease in the peak inspiratory pressure, due to which the ventilation of the ventral and apical parts of the lungs improves. Such changes in gas distribution have the effect of improving alveolar oxygenation and eliminating severe hypoxemia. The PCV mode provides reliable protection against the development of barotrauma due to the specified limitation of pressure growth. Due to the lower probability of creating a flow deficit, breathing performance and patient comfort can improve. Disadvantages of the PCV regimen are that tidal volume is variable and dependent on compliance. With a sudden decrease in airway resistance, insufflation of an uncontrolled volume can lead to overstretching of the alveoli and barotrauma. High early inspiratory flow may exceed the pressure limit if airway resistance is high [4, 5]. In Table 2, we present the results of the examination of patients after two days of invasive artificial pulmonary ventilation.

*Table 2*

**The main characteristics of two compared groups of patients with signs of lung contusion and ARDS, who received two different methods of invasive respiratory support on the third day of its implementation (M±SD)**

| Indicator / Group | Group VCV respiratory support | Group PCV respiratory support | p |
|---|---|---|---|
| Number of patients, n | 20 | 20 | 1 |
| Pulse rate, 1/min. | 90.20±5.47 | 88.35±5.03 | 0.27 |
| Systolic blood pressure, mm Hg | 117.75±5.73 | 121,25±6,86 | 0.09 |
| Diastolic blood pressure, mm Hg | 73.75±4.55 | 74.75±4.44 | 0.49 |
| Mean arterial pressure, mm Hg | 88.42±4.31 | 90.25±4.85 | 0.21 |
| Need for vasopressors, n | 0 | 0 | 1 |
| Perfusion index, % | 4.35±0.63 | 4.38±0.53 | 0.89 |
| $SpO_2$% with air ventilation, % | 91.65±1.69 | 91.75±1.86 | 0.86 |
| $SpO_2$% during ventilation with a gas mixture with 40% oxygen, % | 98.30±0.80 | 98.35±0.81 | 0.85 |
| $FiO_2$ to ensure $SpO_2$% = 96% | 0.30±0.04 | 0.29±0.05 | 0.83 |
| $P_ECO_2$, | 48.85±1.04 | 49.45±1.32 | 0.12 |
| Static pulmonary compliance, ml/cm $H_2O$ | 51.65±4.73 | 51.85±4.45 | 0.89 |
| Hemoglobin concentration in blood, g/l | 111.85±10.40 | 113.70±8.16 | 0.54 |

The results of the survey showed that when comparing the effectiveness of two types of respiratory support, no significant differences had founded in the state of hemodynamics and integral indicators of the state of the respiratory function of patients. On the 28th day after the injury, all patients were alive and transferred from the intensive care unit. Thus, we believe that respiratory support was successful in all patients.

**Conclusion.** Our study showed that the provision of invasive respiratory support in patients with pulmonary contusion and signs of ARDS using volume and pressure controlled ventilation modes did not reveal the advantage of one of the modes. On the other hand, in our study, there were no patients with signs of grade 3 ARDS. Therefore, the problem requires further observation and development.

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