

1. Introduction

Children are frequently admitted to pediatric intensive care units due to acute respiratory failure [1] and up to 64 % of them need to be mechanically ventilated and later weaned [2]. Diaphragm paresis is common in mechanical ventilated patients and may delay the weaning from the ventilator [3]. Both the early start of weaning and its delay are harmful to the patient. The presence of acute severe malnutrition in children with pneumonia is the independent predictor of worsening outcomes. Patients with malnutrition have longer duration of stay at intensive care unit and mechanical ventilation. The duration of weaning from mechanical ventilation might be high and accompanied by recurrent episodes of lower respiratory tract infections [4].

The aim was to develop strategy of weaning from mechanical ventilation in children with different types of respiratory failure.

2. Materials and methods

The work is based on the own experience of treatment and analysis of medical records of 237 patients aged 1 month – 18 years. It was conducted open prospective randomized non-interventional controlled single-center study in January 2018 – April 2020 at the Department of Anesthesiology and Intensive Care, Danylo Halytsky Lviv National Medical University; Department of Anesthesiology and Intensive Care, Lviv Regional Children Hospital "OCHMATDYT".

The study was conducted in accordance with the requirements of good clinical practice, the Council of Europe Convention on Human Rights and Biomedicine, the Helsinki Declaration of the World Medical Association. The study was approved by the Bioethics Commission of Danylo Halytsky Lviv National Medical University, protocol No. 1, January 30, 2018. All patients' relatives or their legal representatives signed informed consent to participate in the study.

All patients were divided into control group, which included 75 patients who underwent short-term ventilation during elective surgery and who were weaned immediately after surgery and restoration of physiological functions after anesthesia, and patients of study group with acute respiratory failure (n=162), who required invasive mechanical ventilation via endotracheal tube. Patients in the study group were randomized into study group I (83 patients) and received traditional ICU monitoring and treatment and study group II (79 patients), in which we used in addition to traditional monitoring and treatment, proposed by us methods of monitoring and treatment strategy.

CLINICAL AND PHYSIOLOGICAL JUSTIFICATION OF WEANING FROM MECHANICAL VENTILATION IN CHILDREN WITH RESPIRATORY FAILURE

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Abstract: Children frequently are admitted to pediatric intensive care units due to acute respiratory failure and up to 64 % of them need to be mechanically ventilated and later weaned.

The aim was to develop strategy of weaning from mechanical ventilation in children with different types of respiratory failure.

Materials and methods. The work was based on results of treatment of 237 patients aged from 1 month to 18 years old, who were divided into control and study group. Patients of study group were randomized into group I (83 patients) and received traditional ICU monitoring and treatment and group II (79 patients), where was used proposed by us methods of monitoring and treatment.

Results. There was supplemented data on the etiology of respiratory failure in children with taking into account function of diaphragm, changes in hemodynamics, nutritional status, electrolyte balance and central nervous system function. It was established new mechanisms of inadequacy of spontaneous breathing during mechanical ventilation and found causes of unsuccessful weaning from mechanical ventilation. In addition, it was developed a weaning strategy with goal-directed therapy for disorders treatment according the type of respiratory failure and children's age. As a result, important scientific problem was solved and the results of treatment of children with respiratory failure was improved.

Conclusions. It was found that proposed strategy of weaning from mechanical ventilation allowed to reduce the duration of mechanical ventilation and the frequency of complications (reintubations). There were no significant differences in the frequency of tracheostomy among patients of I and II groups.

Keywords: acute respiratory failure, weaning from mechanical ventilation.

To assess age-dependent data, patients were divided into age subgroups: 1 subgroup – children 1 month – 1 year; 2nd subgroup – children 1–3 years; 3 subgroup – children 3–6 years; 4 subgroup – children 6–13 years; 5 subgroup – children 13–18 years. Stages of the study: 1st day (d1), 3rd day (d3), 5th day (d5), 7th day (d7), 9th day (d9), 14th day (d14), 28th day (d28).

It was compared the effectiveness of a standard approach to respiratory therapy and treatment of comorbidities and the effectiveness of proposed by us additions to this approach. The standard approach included lung protective mechanical ventilation, assessment and correction of nutritional deficiency according to indicators of body weight deficit in comparison with proper body weight for age and the level of total serum protein and albumin, routine checking and correction of serum sodium, potassium and chlorine levels, non-invasive prolonged monitoring of hemodynamics with determination of stroke volume, cardiac output, cardiac index, stroke index, assessment of patients' consciousness level according to the Glasgow coma scale and taking into account the patient's history of bulbar disorders. Our proposed additions to intensive care included: the use of diaphragm-protective mechanical ventilation strategy; assessment and correction of nutritional deficiency according to body weight and height for

age, body mass index for age, circumference of middle third of shoulder, serum transthyretin level, the absolute count of lymphocytes in the peripheral blood; monitoring of serum phosphorus, magnesium and ionized calcium and correction of serum magnesium and ionized calcium, correction of the parameters, received during non-invasive prolonged monitoring of hemodynamics during mechanical ventilation and weaning from mechanical ventilation, checking level of consciousness according to FOUR scale, determining the level of sedation according Ramsay scale, performing daily breaks in sedation, checking presence of bulbar disorders (absence of cough and swallowing reflexes).

Statistical analysis of the study results was performed using MS Excel 2017 with the calculation of arithmetic mean (X) and standard deviation (σ). Parametric criteria (Student's t-test) were used and the difference was considered statistically significant at $p < 0.05$.

3. Results

The presence of acute severe malnutrition in children with pneumonia is the independent predictor of worsening out-

comes. Patients with malnutrition have longer duration of stay at intensive care unit and mechanical ventilation. The duration of weaning from mechanical ventilation might be high and accompanied by recurrent episodes of lower respiratory tract infections.

Severe acute malnutrition was detected in 23.1 % of patients in 1st group (6 patients of 26); in 27.3 % in 2nd group (3 patients of 11); one patient in 3rd group (the only patient in this group); 6.3 % of patients in 4th group (1 patient of 16) and 16.7 % in 5th group (1 patient of 6). Obesity was diagnosed in patients of 2nd and 4th groups, where it was 18.2 % (2 patients of 11) and 6.3 % (1 patient in 6), respectively.

We analyzed the findings and were identified the unidirectional changes in body mass index to age and weight to height in patients of all groups: the patients included in the analysis were found to have the same level of impairment in both body mass index and weight to height.

To determine the prevalence of changes in total serum protein level, we were divided all patients into subgroups of patients with hypoproteinemia below 60 g/l (patients with hypoproteinemia) and patients with total protein levels over 60 g/l (patients without hypoproteinemia). We found that on d₁ stage of the study at 1st group of patients hypoproteinemia was in 62.5 % (15 of 26), at the d₃ stage – in 40 % of patients (10 of 26); at the d₅ stage – in 20 % of patients (5 out of 26).

In patients of 2nd group hypoproteinemia was observed in 36.4 % (4 of 11) at d₁ study stage; in 18.2 % of patients (2 of 11) at d₃ stage. The only patient of 3rd group had hypoproteinemia at stages d₁ and d₃. In addition, in 4th group hypoproteinemia was found in 25 % of patients (4 of 16) at the d₁ study stage, equally in 6.25 % at d₃ and d₅ stages (in 1 of 16). In 5th group of patients, these disorders were observed in 33.3 % at d₁ study stage (2 of 6 patients) and in 16.7 % at d₃ study stage (1 of 6 patients).

We evaluated the dynamics of total protein level along the study in patients with hypoproteinemia below 60 g/l who were included in 1st and 2nd groups and find out that total protein gradually increased from 51.05 [44.12; 56.81] g/l on d₁ to 53.77 [49.13; 55.69] g/l at d₅ stage, whereas for patients in 2nd group it had tendency for decreasing from 56.09 [53.05; 57.2] g/l to 53.7 [52.15; 60.38] g/l from d₁ to d₃ study stage.

4. Discussion

Acute severe malnutrition is a common problem among patients with acute respiratory failure with a high incidence among children aged 1 month to 1 year.

Approximately the same level (from 6.1 % to 17.4 %) of the prevalence of malnutrition is described in the publication McCarthy A. with co-authors among patients in children's hospitals, and it may be even higher in patients in intensive care units [4]. And in a cross-sectional study of Dogan and colleagues [5], the prevalence of moderate and severe malnutrition was obtained in 43.4 % of cases, when it was assessed on the basis of body mass index relative to age. Also, the authors of many publications [6–10] demonstrate that the frequency of malnutrition in children depends on the method or scale by which it is verified, so when comparing data on the prevalence of this disorder should take this fact into account.

In this work for the first time were obtained new data on diaphragm function, was implemented into clinical practice the method of checking the function of diaphragm in children. It gives us opportunity to develop the strategy how to change the ventilation parameters depending on data received with ultrasound of the diaphragm. Therefore, we might use pa-

tient-based individualized approach of mechanical ventilation. We found the diagnostic value of determining the function of the diaphragm in children undergoing mechanical ventilation in terms of their readiness to wean from mechanical ventilation and scientific data on how diaphragm dysfunction affects the results of weaning.

It was shown advantages of providing diaphragm-protective mechanical ventilation in addition to lung-protective strategy in children with acute respiratory failure both during the entire period of respiratory therapy and weaning from mechanical ventilation.

We were the first to develop and implement in clinical intensive care an algorithm for weaning from children in children, taking into account previous unsuccessful weaning attempts, data on nutritional status, electrolyte balance, hemodynamic parameters, neurological status and diaphragm function.

It was found that for patients with hypoxemic and combined hypercapnic-hypoxemic type of acute respiratory failure in the presence of bulbar disorders and inability to swallow liquid food, the prognosis for weaning was favourable in the case of securing lower airways with a cuffed tube with maintenance pressure in a cuff not less than 15-20 mm Hg.

It was found that combination of such indicators as Paediatric rapid shallow breathing index >6.2 breaths/min/ml/kg, amplitude of the diaphragm movement less than 8 mm, fraction of diaphragm thickening less than 15 % or more than 45 %, tidal volume less than 4.5 ml/kg, PS more than 12 cm H₂O to achieve minimal respiratory system load, no spontaneous cough reflex, less than 11 points according to Glasgow coma scale, and two or more previously unsuccessful weaning attempts give us unfavourable prognosis for weaning from mechanical ventilation. In patients 1 month – 1 year old acute severe malnutrition was an independent predictor of unsuccessful weaning. The ratio of transthyretin to C-reactive protein less than 3.5 is an unfavourable factor for effective weaning. It was found that our strategy of weaning from mechanical ventilation allowed to reduce the duration of mechanical ventilation: in patients of the 1st age subgroup by 1.5 times (p=0.08); in patients of 2nd age subgroup – by 2.4 times (p=0.18); in 4th age subgroup – by 1.75 times (p=0.1); in 5th age subgroup – by 4.25 times (p=0.009). In patients of 3rd age subgroup duration of mechanical ventilation increased by 1.1 times (p=0.68). The frequency of complications (reintubations) was reduced in 1st age subgroup by 4.3 times (p=0.02); in 2nd age subgroup – by 3.4 times (p=0.04). There were no significant differences in the frequency of tracheostomy among patients of I and II groups.

Study limitations. Our current study has several limitations. First, neither results assessor nor medical staff, who take care for patients, could not be blinded to group allocation because of the nature of the study. Second, the number of patients, who were included in the study, have to be enlarged in order to achieve significant differences in data which we studied.

Prospects for further research. Further studies are required to evaluate if any of find pathophysiological changes might has impact on 28-days mortality rate in different age subgroups of children.

5. Conclusions

It was found that our strategy of weaning from mechanical ventilation allowed to reduce the duration of mechanical ventilation: in patients of the 1st age subgroup by 1.5 times (p=0.08); in patients of 2nd age subgroup – by 2.4 times (p=0.18); in 4th age subgroup – by 1.75 times (p=0.1); in 5th age subgroup –

by 4.25 times ($p=0.009$). In patients of 3rd age subgroup duration of mechanical ventilation increased by 1.1 times ($p=0.68$).

The frequency of complications (reintubations) was reduced in 1st age subgroup by 4.3 times ($p=0.02$); in 2nd age subgroup – by 3.4 times ($p=0.04$). There were no significant differ-

ences in the frequency of tracheostomy among patients of I and II groups.

Conflicts of interest

The authors declare that they have no conflicts of interest.

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