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Non-invasive Ventilation During Sanitary Aircraft Evacuation in a Patient with Severe Community-acquired Pneumonia

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BACKGROUND We report the experience of sanitary aviation evacuation of a patient with severe respiratory failure on the background of community-acquired pneumonia using mask non-invasive ventilation. The use of this method of ventilation of the lungs made it possible to avoid undesirable consequences arising from the transfer of the patient to artificial ventilation of the lungs and to transport him safely to a specialized medical institution in order to continue treatment. The described method of preparing a patient with respiratory failure before aviation transportation has shown its effectiveness during the flight and may be recommended for use by airmobile crews when carrying out long-distance evacuation

Keywords: community-acquired pneumonia, aviation evacuation, non-invasive ventilation, functional transportability

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ABS – acis-base balance
ALV – assisted lung ventilation
BE – base excess
BP – blood pressure
CT – computed tomography
FiO_2 — fractional inspired oxygen
HCO_3 – bicarbonates
HR – heart rate
MAM – medical aircraft module
NIALV – non-invasive assisted lung ventilation
O_2 — oxygen
PaO_2 — partial oxygen pressure in arterial blood
PaO_2/FiO_2 — oxygenation ratio
PCO_2 — partial carbon dioxide pressure
pH — acidity
PO_2 — partial oxygen pressure
RICU – resuscitation and intensive care unit
RR – respiratory rate
SAE – sanitary aircraft evacuation
SpO_2 — oxygen saturation
TCO_2 — total carbon dioxide

BACKGROUND

According to the Federal Law "On the Basics of Citizen Health Protection in the Russian Federation", sanitary aircraft avacuation (SAE), is medical transportation of patients using aircraft. The main advantage of the SAE is the quick delivery of critically ill patients to the place of medical care, and the modern equipment of specialized medical modules provides the ability to evacuate patients with life-saving functions [1, 2]. Currently, the need for an SAE in the development of severe pneumonia with impaired gas exchange, requiring mechanical ventilation, is 14% at the Ministry of Defense [1]. It is important that with the development of respiratory failure, SAE has an additional risk of worsening of respiratory disorders due to exogenous hypobaric hypoxia [3]. The risk of respiratory failure requires an objective assessment before the evacuation. Violations of gas exchange, which did not require prosthetics of the respiratory function at normal atmospheric air pressure, may lead to severe hypoxia during the flight and require emergency prosthetic function of external respiration. Therefore, as a rule, such patients are ventilated through the endotracheal tube even before the SAE. The epilaryngeal tube may be an alternative to tracheal intubation. The problem of the epilaryngeal tube is unreliable protection of the respiratory tract from aspiration due to depression of consciousness and muscle relaxation. An option to keep the patient cinscious and reduce the risk of aspiration is respiratory support with NIALV through a face mask.

Description of the clinical case.

In this report, we present a clinical case of conducting NIALV during the prolonged SAE in a patient with severe respiratory failure on the background of community-acquired bilateral pneumonia.

A 32-year-old male parient M. asked for primary medical care with complaints of general weakness and malaise two days after the onset of the disease. When examined by a doctor, a temperature rise to 38.0°C was detected, severe chills, hard breathing was heard during auscultation of the lungs, dry single rales, no pathology was detected in the other organs and systems. The patiemt was hospitalized with a preliminary diagnosis of "acute bronchitis". The next day, moist rales appeared in the basal regions of the lungs on both sides, hyperthermia persisted up to 38.6°C. According to the results of chest radiography, left-sided lower lobe pneumonia was detected. Oral administration was prescribed: Amoxicillin with clavulanic acid 1.2 g, 2 times a day, Azithromycin 500 mg 1 time per day, paracetamol 1 g 2 times per day, Bromhexine (syrup) 10 ml 3 times per day and and Budesonide inhalation through a compression inhaler 3 times a day [8]. Despite the treatment, the dynamics of the disease was negative: hyperthermia persisted, respiratory insufficiency increased, dyspnea appeared, respiratory rate increased to 24 breaths per min, saturation against respiration with atmospheric air decreased to 93%. It was decided to hold a telemedicine consultation with specialists of the central hospital. During the consultation it was decided to evacuate the patient in order to provide specialized medical care [4].

When examining a patient by specialists of the airmobile crew on the 5^{th} day from the onset of the disease the patient's condition was regarded as severe. At the time of inspection, the consciousness was clear, without neurological symptoms, meningeal signs were not determined, the body temperature was 38.0°C. Diffuse cyanosis of the skin was noted, no pathological lesions were detected. Independent breathing with the participation of auxiliary muscles, on the background of O_2 insufflation through the face mask with a flow of 5–6 l/min. RR was 20–22 breaths/min, SpO_2 95%. Without oxygen insufflation, there was a feeling of lack of air, inspiratory dyspnea to 24–26 breaths per min while the saturation decreased below 94%. Auscultation of the lungs revealed hard breathing, weakened in the upper and low back departments on both sides, wheezing over the entire lungs, fine crackles in the upper and lower parts. Sinus tachycardia up to 112 beats per min, BP 137/72 mm Hg. Urination was independent, the rate of diuresis was not reduced. No patholigic changes in the other organs and systems. Laboratory diagnostics was not performed due to lack of resources in the institution.

During the preparation of the patient for the SAE, as well as during transportation, the analysis of gas exchange disorders and the acid-base balance (ABB) of the blood were investigated using an *i-STAT* portable analyzer manufactured by *Abbott* (USA) with a set of “G3 +” cartridges which measure following parameters: pH, PCO_2, PO_2, TCO_2, HCO_3, BE, PaO_2, PaO_2/FiO_2.

The patient was evacuated using the medical aircraft module MAM.9520.000 installed on board the IL-76MD aircraft. THe respiratory support was performed with *CareFusion Pulmonetic LTV* 1200 Series IVL *Ventilator Inc.* (USA), through the oronasal face mask for NIALV *Dräger NovaStar*. The vital functions were monitored by the "*Weinmann Corpuls* 3" system (Germany).

The severity of gas exchange disorders was regarded as compensated, that is why NIALV was chosen. In order to study the possibility of carrying out NIALV during sanitary evacuation, it was decided to perform a trial session, select ventilation parameters and adapt the patient to the ventilator (Table 1). For the initiation of NIALV, the technique recommended by the All-Russian public organization “Federation of Anesthesiologists and Resuscitators” [5, 6] was used. The patient has adapted to the ventilator in *Non-invasive Positive Pressure Ventilation (NPPV)* with the following ventilation parameters: pressure support 8 cm Aq., positive pressure at the end of an exhalation 5 cm Aq, FiO_2 50%. Against this background, the minute pulmonary ventilation amounted to 6–8 l/min, tidal volume was up to 400–500 ml, RR was 15–16 breaths per min. The leakage of the oxygen-air mixture was 5–15%. Hemodynamic parameters remained stable (BP 135/80 mm Hg; heart rate (HR) 95 beats per min). The monitoring of gas exchange violations exchange in the lungs was performed before and after initiation of NIALV (Table 1).

Table 1

The arterial blood gas composition before and during the test NIV

Measurement stage	pH	$PaCO_2$, mm Hg	HCO_3, mmol/l	BE, mmol/l	TCO_2, mmol/l	PaO_2, mm Hg	SpO_2, %	PaO_2/FiO_2
Insuflation O_2, FiO_2=40%	7.51	31	24.7	2.6	25.7	72	95	180
With NIALV, FiO_2=50%	7.50	32	23.2	2.0	23.4	128	98	256

Notes: BE - base excess; NIALV - non-invasive assisted lung ventilation

The patient was transported to the airfield by ambulance in the supine position and oxygen insufflation through the face mask with a flow of 5–6 l/min using the *Weinmann* ventilator “*LIFE - BASE Mini* II”. After boarding, the patient was placed on an MAM stretcher (medical aircraft module), and before take-off, oxygen insufflation with the same flow was continued and hemodynamic and respiratory parameters were monitored. The condition remained severe, stable, the patient had no active complaints.

The take-off period was satisfactory. Later, 15 minues after taking-off, he had complaints about the feeling of lack of air, anxiety, dyspnea, saturation decreased to 89%, RR increased to 29–30 breaths per min. At the same time, the heart rate increased to 122 beats per min, blood pressure grew up to 130/90 mm Hg. An attempt to increase the oxygen supply through the face mask did not ensure the patient’s need and signs of respiratory failure continued to progress. A decision was made to start respiratory support with the help of the NIALV using the Pulmonetic *LTV* 1200 ventilator. The patient quickly adapted to assisted ventilation with parameters that were selected during the test session. Against this background, the patient noted relative comfort during ventilation, did not complain about the feeling of lack of air, the RR dropped to 14–16 breaths per min, the saturation increased to 96%. Against the background of physiological comfort, the patient fell asleep.

Flight duration at altitudes of 8,000–9,000 m was 5 h 21 min, while the total time of the NIALV was 5 h 25 min. The dynamics of indicators of gas and acid-base balance of arterial blood are given in table 2.

Table 2

Acid-base balance of gas composition

Measurement stage	pH	$PaCO_2$, mmHg	HCO_3, mmol/l	BE, mmol/l	TCO_2, mmol/l	PaO_2, mmHg	SpO_2, %	PaO_2/FiO_2
Before takeoff FiO_2=40%	7.51	31	24.7	2.6	25.7	72	95	180
After 15 minutes of flight, at an altitude of 9,000 m, FiO_2=40%	7.50	28	22.2	2.0	23.0	58	89	145
After 4 hours of flight, at an altitude of 9,000 m, FiO_2=50% with NIALV	7.46	33	24.3	2.1	24.0	131	98	262
30 min after landing, FiO_2=40%	7.44	32	22.8	2.3	23.8	80	97	200

Notes: BE — base excess; NIALV — non-invasive assisted lung ventilation

During the flight, the position of the face mask was periodically monitored. Taking into account the high consumption of oxygen at NIALV and the duration of the evacuation, the MAM was fully supplied with standard oxygen cylinders, which were enough for the entire period of NIALV. After the onset of NIALV during the flight, the blood pressure, heart rate, and SpO_2 parameters remained stable. The parameters for monitoring hemodynamics and hemoglobin saturation during the flight are presented in Table 3.

Table 3

Heart rate and oxygen saturation of hemoglobin

Measurement stage	BP, mm Hg	HR, beats per min	SpO_2, %
An the hospital. FiO_2= 40%	137/72	96	95
15 min flight at an altitude of 9000 m, FiO_2=40%	142/90	122	89
4 hours at a flight altitude of 9000 m , FiO_2=50%. NIALV	134/73	94	97
30 min after landing. FiO_2=40%	130 /	92	97

Notes: BE — base excess; NIALV — non-invasive assisted lung ventilation

After landing, the respiratory support was turned off, the patient continued breathing through the face mask with oxygen insufflation with a flow of 5–6 l/min. The patient was transferred to the central hospital via reanimobile.

Upon admission to the resuscitation and intensive care unit, computed tomography (CT) scan of the chest organs was performed. Bilateral pneumonic infiltration was detected with significant peribronchial infiltration in S7 of the right and in S9, S10 of the left lung (Fig. 1).

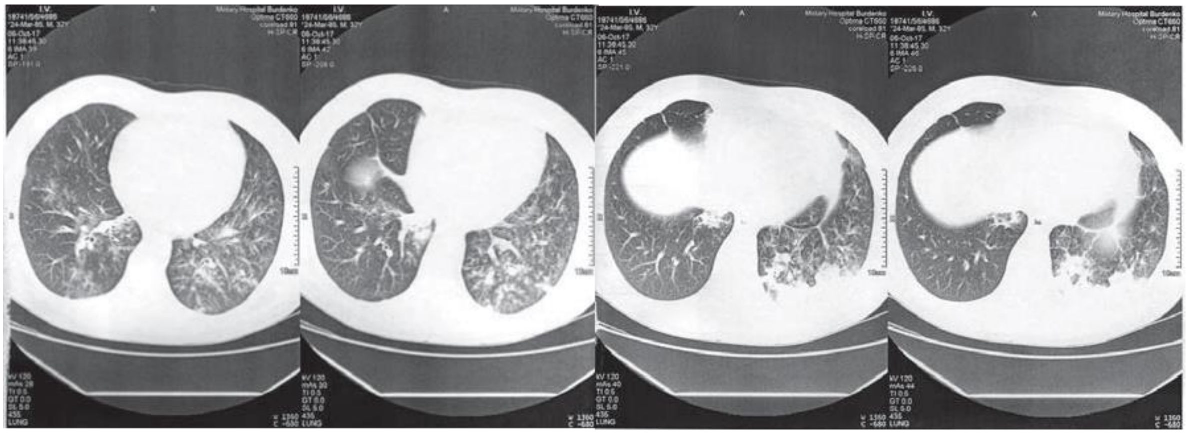

Fig. 1. The CT scan of the lungs, when admitted to hospital

Taking into account the positive experience of respiratory support during the SAE, respiratory therapy with NIALV sessions was continued in the RICU. Drug treatment of community-acquired pneumonia: antibacterial therapy with a combination drug (Imipenem/Cilastatin) 3 g/day, Moxifloxacin 400 mg/day, mucolytics. Against the background of complex intensive therapy, there was positive dynamics over the next 3 days, which was manifested by improved pulmonary gas exchange, decreased respiratory failure, normalization of body temperature, improved general condition, and an increase in tolerance to physical exertion. Saturation of hemoglobin with oxygen when breathing in atmospheric air was more than 95%.

On the 4th day from the moment of admission to the hospital, the patient was transferred from the RICU to a specialized department for further treatment and observation. He was discharged on the 21st day in a satisfactory condition. The check CT on the 10th day showed a decreased infiltration in both lungs (Fig. 2).

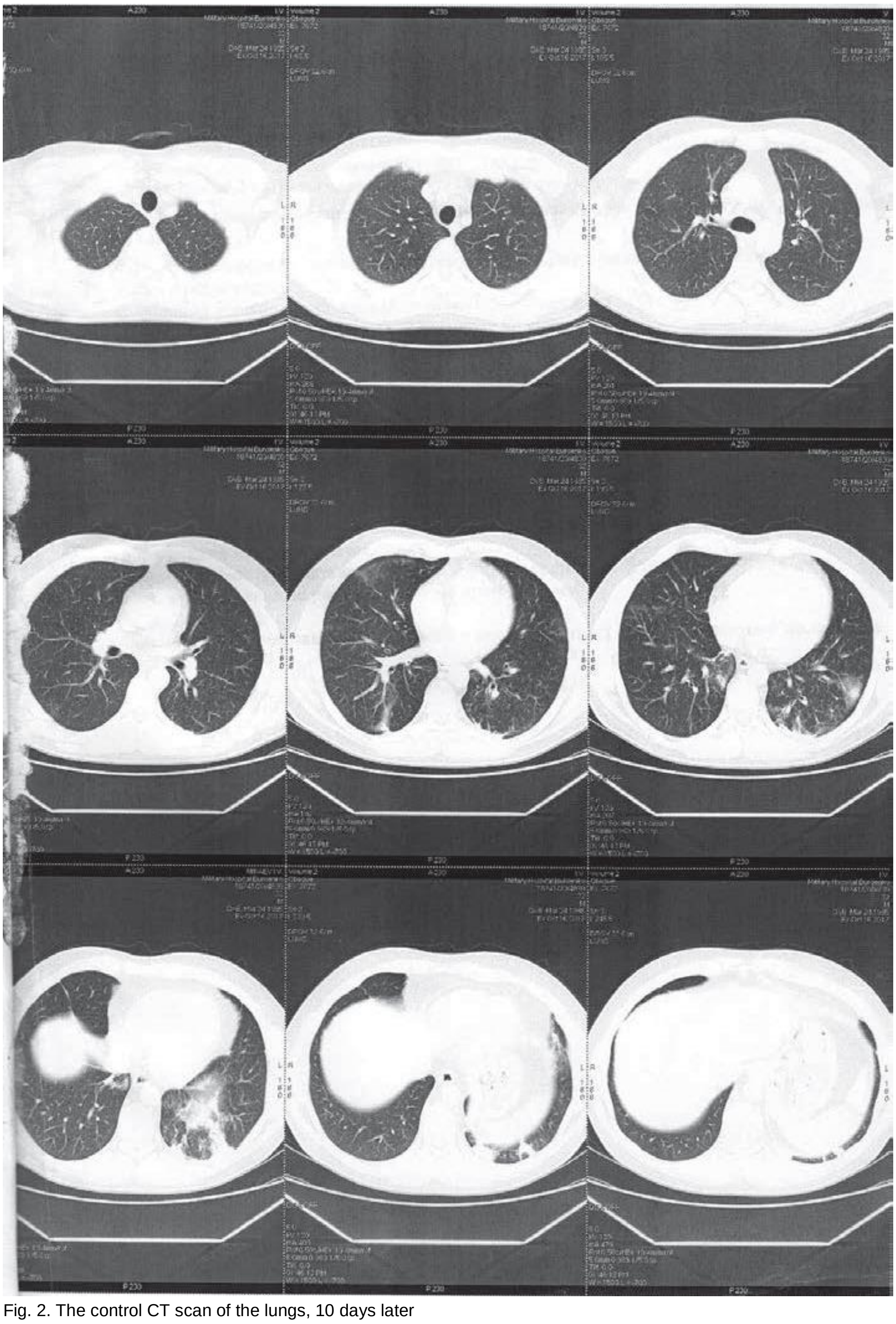

Fig. 2. The control CT scan of the lungs, 10 days later

DISCUSSION

According to modern concepts of respiratory therapy of severe pneumonia, NIALV attracts the attention of clinicians with a number of advantages over mechanical ventilation. The positive effects of NIALV include: preventing the "mechanical" and infectious complications inherent in tracheal intubation, maintaining the natural protection mechanisms of the upper respiratory tract, physiological cough, the patient's ability to talk, swallow, eat, cough up sputum, reduce the risk of ventilator-associated pneumonia and nosocomial infections, as well as quick leaving respirator. In addition, during transportation of the patient via aircraft, the risk of uncontrolled overfitting of the cuffs of the endotracheal tube or epilaryngeal tube, depending on the barometric air pressure in the aircraft cabin and flight altitude, is of great importance.

The experience of this SAE showed that the positive results of evacuation depending on several factors: the severity of the patient's condition, the level of professional training of the personnel of the airmobile crew and the technical ability to ensure the transportation of the patient in a critical condition.

The data obtained during the SAE confirm that exogenous hypobaric hypoxia affects the patient during the flight. Respiratory failure, which did not require mechanical ventilation at normal atmospheric pressure, required respiratory support after taking off and barometric pressure decrease in the cabin. According to the literature, the barometric air pressure in the cabin of the aircraft at an altitude of 9,000 m is maintained at 581–567 mm Hg, which corresponds to 2,200–2,400 m above sea level, while the partial pressure of oxygen in the alveolar air is 76–65 mm Hg. [3]. The risk of an increase in respiratory failure must be taken into account when conducting pre-evacuation preparation in order to decide whether to ventilate the lungs according to the tactics chosen before or during SAE.

The effectiveness of the selected method of respiratory support in the presented specific clinical case may indicate the possibility of using the described method in certain clinical situations: during SAE in patients with respiratory failure caused by severe pneumonia with preserved clear consciousness and willingness to cooperate, in case if the trial session NIALV was successful, the presence of an adequate supply of oxygen, taking into account the trial session and leakage compensation.

However, in certain cases, NIALV may not be enough to ensure gas exchange in severe respiratory failure [2, 6]. The reasons for the termination of NIALV and the onset of mechanical ventilation with tracheal intubation are: large criteria (apnea, loss of consciousness, instability of hemodynamics, and psychomotor agitation, making it impossible to perform NIALV); small criteria (no improvement in blood gas and pH after 4 hours of NIALV, severe dyspnea at rest, NIALV more than 35 per minute, SpO_2 less than 90%, participation of auxiliary muscles in the act of breathing, PaO_2 less than 45 mm Hg, PaO_2/FiO_2 less than 200, hypercapnia more than 60 mm Hg or a progressive increase in $PaCO_2$, critical respiratory acidosis (blood pH less than 7.25), progressing signs of encephalopathy, *APACHE* II less than 24 and *SAPS* more than 15) [7, 9, 10]. One small or two small criteria that persist for one hour are sufficient to make a decision on tracheal intubation.

CONCLUSION

Modern methods of respiratory support make it possible to keep a patient conscious, preserve natural mechanisms of protection of the upper respiratory tract and reduce the risk of ventilator-associated pneumonia. The use of non-invasive assisted ventilation as a respiratory support in a patient with respiratory failure on the background of community-acquired pneumonia allowed us to successfully carry out sanitary aircraft evacuation to the place of specialized medical care. The experience of sanitary aircraft evacuation showed the need to take into account the factor of development of hypobaric hypoxia to ensure gas exchange. In case of choosing a non-invasive assisted ventilation, the key to successful initiation of this method of ventilation is to conduct a test session in preparing the patient for transportation.

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