Kuzmenko Tetiana, Vorotintsev Sergiy. Individualized perioperative respiratory support as a way of preventing postoperative pulmonary complications in abdominal surgery. Journal of Education, Health and Sport. 2019;9(6):522-533. eISNN 2391-8306. DOI http://dx.doi.org/10.5281/zenodo.3333799
http://ojs.ukw.edu.pl/index.php/johs/article/view/7152

The journal has had 7 points in Ministry of Science and Higher Education parametric evaluation. Part B item 1223 (26/01/2017).
1223 Journal of Education, Health and Sport eISSN 2391-8306 7

The authors declare that there is no conflict of interests regarding the publication of this paper.
Received: 10.06.2019. Revised: 24.06.2019. Accepted: 28.06.2019.

INDIVIDUALIZED PERIOPERATIVE RESPIRATORY SUPPORT AS A WAY OF PREVENTING POSTOPERATIVE PULMONARY COMPLICATIONS IN ABDOMINAL SURGERY

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Abstract

Introduction. Indicators of postoperative pulmonary complications (PPCs) in abdominal surgery being in the range of 17% to 88%, their development leads to an increase in morbidity and mortality, an extension in the length of stay in the medical institution, as well as material costs. In recent years, there has been a clear shift in the paradigm from the prevention of death and complications caused by lungs damage the prevention of the development of the complication. Prevention of pulmonary complications should have a comprehensive approach, but there is still no clearly formulated perioperative tactic for the management of patients with moderate or high risk of trouble development and with healthy lungs, taking into account the individual peculiarities of pulmonary tissue. **Objective.** To create and evaluate of the effectiveness of perioperative individualized respiratory support in patients with moderate or high risk of development of postoperative pulmonary complications

in abdominal surgery. **Materials and methods.** The study consisted of two parts. The first retrospective partcomprised analysis of the medical histories data of 45 patients, who were included in the group 1. The prospective part of the study included 47 patients of the group 2, who had perioperative individualized respiratory support, which included intraoperative protective ventilation with low tidal volume (7 ml/kg ideal body weight), individual level of positive end-expiratory pressure and using the maneuver of the recruiting of the alveoli, sessions of the incentive spirometry for 2 days prior to surgery, and continued in the first postoperative week or only postoperative. Patients of both groups were operated onthe upper abdominal organs by open procedure, operation time was more than 2 hours, all patients had an ARISCAT score ≥26 points. Postoperative pulmonary complications development (atelectasis, pneumonia, pleural efforts, hypoxemia, pneumothorax) was monitored in the groups in the first week of the postoperative period. The statistic analysis of the data was performed with using the Microsoft Excel 2013 and Statistica for Windows 6.0 programs. When comparing the groups according to the clinical outcome, the relative risk (RR) and odds ratio (OR) were determined and then confidence intervals (95 % CI) were calculated. The difference in values was considered significant at $p < 0.05$. **Results.** During the first 7 days after the operation in the group of the retrospective part of the study of PPCs developed in 35 patients (78%), of which 31 patients (69%) had pulmonary atelectasis, 11 patients (24%) got pneumonia, pleural effusion was stated in 21 patients (47%) and one (2%) produced hypoxemia. In the prospective part PPCs were recorded in 11 patients (23%). Of these, 8 patients (17%) had pulmonary atelectasis, 4 (9%) got pneumonia and 5 (11%) received pleural effusion. In both groups no cases of pneumothorax were recorded. A comparison of clinical outcomes showed that patients in group 2 had a significantly lower risk of developing atelectasis in the first week after surgery than patients in group 1: RR 0.2471 (95% CI 0.1276-0.4786), $p<0.0001$; OR 0.0926 (95% CI 0.0345-0.2489), $p<0.0001$. A similar trend was observed for postoperative pneumonia (RR 0.3482 (95% CI 0.1196-1,0139), p=0.0530; OR 0.2875 (95% CI 0.0841-0.9833), p=0.0469) and pleural effusion (RR 0.2280 (95% CI 0.0940 - 0.5526), p=0.0011; OR 0,9131 (95% CI 0.0454 – 0.4074), p=0.0004). However, the risk of hypoxemia and pneumothorax in the prospective study group did not decrease if to compare with the retrospective (hypoxemia: RR 0.3194 (95% CI 0.0134 – 7.6434), p=0.4911; OR 0.03123 (95% CI 0.0124 – 7.8682), p=0.4796; pneumothorax: RR 0.9583 (95% CI 0.0194-47.3007), p=0.9829, OR 0.9579 (95% CI 0.0186 -49.3043), p=0.9829). **Conclusions.** Perioperative individualized respiratory support in patients with a moderate and high risk of development of postoperative pulmonary complications is an effective method for reducing

the number of atelectasis, pneumonia and pleural effusion development after the upper floor of the abdominal cavity open surgical interventions.

Key words: postoperative pulmonary complications, perioperative respiratory support, individualized ventilation.

Introduction. Indicators of postoperative pulmonary complications (PPCs) in abdominal surgery being in the range of 17% to 88%, their development leads to growth of morbidity and mortality, an increase of the stay duration in the medical institution, as well as material costs [1]. Mechanical ventilation of the lungs (MV) is one of the main components in general anesthesia in abdominal surgery, but MV can in itself cause damage to the lung tissue (ventilator-associated lung injury/VALI) and respiratory muscles.

Recently, there has been a clear shift in the paradigm from the prevention of death and complications caused by lungs damage to the lungs to the preventing the development of complication. It is believed that prevention of the development of PPCs is possible by applying a protective ventilation strategy that combines the use of low tidal volume (TV) and different values of positive end-expiratory pressure (PEEP), which can be complemented by the holding recruitment maneuver of the lung (RM) [2 , 3]. It has been proved that protective ventilation reduces the mortality of patients with both injured and intact lungs [4], as well as during short-term intraoperative MV [5]. However, the results of research by different authors differ, which may be due to the use of different levels of PEEP and values of TV. In addition, the level of PPCs remains high in patients with moderate or high risk of their development.

Selection of individualized ventilation parameters is mainly used for patients with acute respiratory distress syndrome (ARDS). The strategy of individualization is based on the definition of the optimal value of the tidal volume and the selection of the PEEP for improving the gas exchange in the damaged lungs. As for the use of individualized respiratory support in patients with intact lungs during abdominal operations, clinical trials are ongoing, but no results are still available [6].

Perioperative optimization of the lung function helps to reduce the number of PPCs, it includes - refusal of smoking for 4-6 weeks before surgery, correction of pharmacotherapy of bronchial asthma and chronic obstructive pulmonary disease before planned surgical interventions and various methods of respiratory physiotherapy, including training of respiratory muscles and incentive spirometry (IS) [7]. Data from a multicenter randomized trial in 2018 showed that the conduct of perioperative physiotherapy in patients scheduled on upper organs of the abdominal cavity reduced the incidence of PPCs twice, pneumonia in

particular [8]. However, for today there are conflicting data about the effectiveness of IS in the pre- and postoperative period [9, 10].

The prevention of PPCs should have an integrated approach, but there is still no clearly formulated perioperative tactic for the management of patients with moderate or high risk of them development and healthy lungs.

Objective. To create and evaluate of the effectiveness of perioperative individualized respiratory support in patients with moderate or high risk of development of postoperative pulmonary complications in abdominal surgery.

Materials and methods. The study consisted of retrospective and prospective parts. Prior to the beginning of the prospective study, all patients signed an informed consent. Inclusion criteria included: age older than 18 years, risk assessment of PPCs development on the ARISCAT scale ≥26, completed/planned upper abdominal surgical procedures, duration of which more than 2 hours. Exclusion criteria were: age <18 years, pregnancy, ASA V, hemodynamic instability (cardiac index <2.5 l/min/m2, and/or need for inotropic support), intracranial lesions or brain tumors, history of mechanical ventilation in the latest fortnight, history of pulmonary surgery, lung disease of any etiology, patient's refusal to participate in the study, acute respiratory failure occurrence in the first 7 days of the postoperative period. The retrospective part of the study involved to analysis of the medical history data of 45 patients who underwent open upper abdominal surgery. The prospective part of the study included 47 patients who underwent similar surgical procedures. Patients in the retrospective part of the study were included in group 1, those in the prospective part were inserted in group 2.

In both groups, the following indices were evaluated: demographic data, height, weight, ideal body weight (IBW)which was calculated according to Devine's formula [11],body mass index (BMI), concomitant pathology, ASA class, ARISCAT score, operative duration, duration of MV.

General anesthesia for all patients was carried out according to the following scheme: premedication - metoclopramide 10 mg, dexamethasone 4 mg, atropine 0,3-1 mg / platyphilin 1,0, fentanyl 1-1,5 mcg/kg; induction - fentanyl 2-3 mcg/kg, sodium thiopental 3-6 mg/kg / propofol 2 mg/kg, myoplegia - atracurium 0.3-0.6 mg/kg / arduan 0.04-0.06 mg/kg; maintenance of anesthesia - propofol 4-12 mg/kg/h or sevofluran 1-4 vol%/2-4 l, fentanyl 3-10 mcg/kg/h, atracurium 0.2-0.4 mg/kg / arduan 0,04-0.06 mg/kg. Some patients in both groups (1 group 7/45 (15%) and 2 group 10/47 (21%)) had a combined anesthesia. The depth

of anesthesia and degree of myorelaxation in group 2 were determined with the help of BIS monitoring by the UTAS monitor, the level of consciousness was maintained within 40-60.

In prospective part of study intraoperative MV was carried out by the "Leon" apparatus in a forced mode with volume control. The ventilation parameters were protective, i. e. the tidal volume 7 ml/kg IBW, using the maneuver of the recruiting of the alveoli and the selection of individual levels of the PEEP. Basic parameters of the ventilation were the following: FiO2 - ≥40% to maintain SpO2 ≥93%, ratio of inhalation / exhalation - 1: 2, respiratory rate (RR) was determined by the level of CO2 at the end of the exhalation (EtCO2) 35-37 mmHg, Pplat≤30 cm in water, Ppeak ≤35 cm of water, Pdrive ≤15 cm of water.

For denitrogenisation and increasing the duration of safe apnea, in group 2, pre-oxygenation was performed at a flow of 8 l/min for 5 minutes, followed by orotracheal intubation. The recruitment maneuver (RM) was performed immediately after intubation of the trachea, and then it was used if necessary. The method of conducting RM was the following: on the ventilator we set the level of PEEP 5 cm of water, the inhalation/exhalation ratio is 1 to 1, the RR is 6 breaths per minute, and then a gradual increase in tidal volume by 4 ml/kg of IBW, is performed until a Pplat will reach a level of 30 cm of water, at this level three breaths are carried out, and then the parameters are returned to the initial levels.

Individual level of PEEP was selected according to the following principle: in ventilation mode with volume control, with the initial pressure level at the end of inhalation of 0 cm of water, the level of PEEP was increased incrementally, every 30 seconds by 1 cm of water to reach the best value of the dynamic pulmonary compliance (Cdyn). During surgical intervention in group 2, Cdyn was determined every 60 minutes on the respirator monitor, if it decreased by more than 20 percent, a RM was performed and the level of PEEP was re-determined.

In the prospective part of the study, scheduled patients and patients with delayed operations had incentive spirometry (IS) exercises with Coach 2 spirometer (Smiths Medical International, UK) for 2 days prior to surgery, and continued in the first postoperative week. Urgent patients had sessions of IS only in the first 7 days after surgery. The incentive spirometer consists of two cylinders, flexible tube with a mouthpiece. A large cylinder is marked with a graduated scale in “ml” and contains a float that rises on the inspiration and shows its volume. On the large cylinder there is an indicator which can be adjusted by a clinician to mark the patient’s inspiratory target. The volume of proper inspiratory capacity of the lungs (LIC) was determined by the nomogram. The scale of the smaller cylinder is

graduated and displays the inspiratory flow rate. Patients inhaled at the such rate when the float remained in the middle position. Exercises were performed in a sitting or semi-sitting position, the incentive spirometer was located in front of a patient. The patient inhaled deeply and slowly through a mouthpiece of the spirometer. After achieving the maximum volume the patient held up this volume constantly for 3–6 seconds, and then breathed out normally into the atmosphere. IS sessions were conducted for 10 minutes every 2 hours, from 10:00 to 20:00. In order to assess the state of the respiratory system and as a criterion for the effectiveness of the method, the LIC was used.

Endpoints of the study were PPCs that developed during the first 7 postoperative days. These included: the presence of atelectasis of the pulmonary tissue, pneumonia, pneumothorax, pleural effusion and hypoxemia. The presence of atelectasis was determined using the clinical sign, such as a decrease in SpO2 ≤ 96% for breath in room air for 5 minutes or in the presence of radiological / ultrasound signs. For the diagnosis of pneumonia, in addition to clinical manifestations, chest X-rays and ultrasound diagnostics were always used. The presence of pneumothorax was also determined at the end of the operation through a clinical examination (auscultation and percussion of the lung area) and, if necessary, radiography or ultrasound were applied. Pleural effusion was determined in the presence of radiological or ultrasound signs of accumulation of fluid in the pleural cavity. If the SpO2 level was lower than 92%, the case was recorded as hypoxemia.

The statistical analysis of the data was performed using the Microsoft Excel 2013 and Statistica for Windows 6.0 programs. The hypothesis for the normality of quantitative indices distribution was analyzed using the Shapiro–Wilk W criterion. The quantitative indices with normal distribution were represented by the mean and standard error (M ± m) or the median and interquartile range (Me [Q25, Q75]) if distribution different from normal and as absolute values for qualitative indices. Mann–Whitney's U-criterion was used as a method of nonparametric statistics to compare the quantitative data. When comparing qualitative variables chi-square test was used. When comparing the groups according to the clinical outcome, the relative risk (RR) and odds ratio (OR) were determined and then confidence intervals (95 % CI) were calculated. The difference in values was considered significant at $p < 0.05$.

Results. The characteristics of demographic and clinical data are presented in Table 1. There were no differences between data of both groups of patients according to all indicators ($p<0.05$), that confirmed our hypothesis for representativeness of the compared groups.

Table 1

Characteristics of patients, M ± m, Me [Q25; Q75] and absolute values

Indicators	Group 1 (n=45)	Group 2 (n=47)	P
Age, years	57,4±18,9	60,3±14,7	>0,05
Sex, m/w	21/24	23/24	
Height, cm	170,8±7,9	173 [163; 178]	
Weight, kg	72 [60; 85]	79,1±14,8	
BMI, kg/m^2	24,7 [21,9; 27,7]	26,4 [23,4; 31,2]	
IBW, kg	64,4±8,8	66,1 [55,2; 71,5]	
ARISCAT, score	42 [38; 46]	42 [34; 42]	
ASA I/II/III, n	-/13/30/2	1/17/26/3	

Patients in both groups underwent various open surgical interventions on the upper abdominal organs for abdominal pathology; the general characteristics are given in Table 2. Patients in group 1 had statistically significantly more surgical interventions in the stomach and duodenum.

Table 2

Types of surgical interventions, absolute values

Types of surgical interventions	Група 1 (n=45)	Група 2 (n=47)	P
Operative intervention on the liver and bile ducts	9	8	0,713
Operative intervention on the stomach and duodenum	18	9	0,029
Operative intervention on the small and large intestines	13	21	0,117
Operation on ventral hernia	5	9	0,284

During the first 7 days after the operation in the group of the retrospective part of the study PPCs developed in 35 patients (78%), of which 31 patients (69%) had pulmonary atelectasis, 11 patients (24%) obtained pneumonia, pleural effusion was observed in 21 patients (47%) and one patient (2%) got hypoxemia (Fig. 1). In the prospective part PPCs were recorded in 11 patients (23%). Of these, 8 patients (17%) had pulmonary atelectasis, 4 (9%) got pneumonia and 5 (11%) received pleural effusion. In both groups no cases of pneumothorax were recorded.

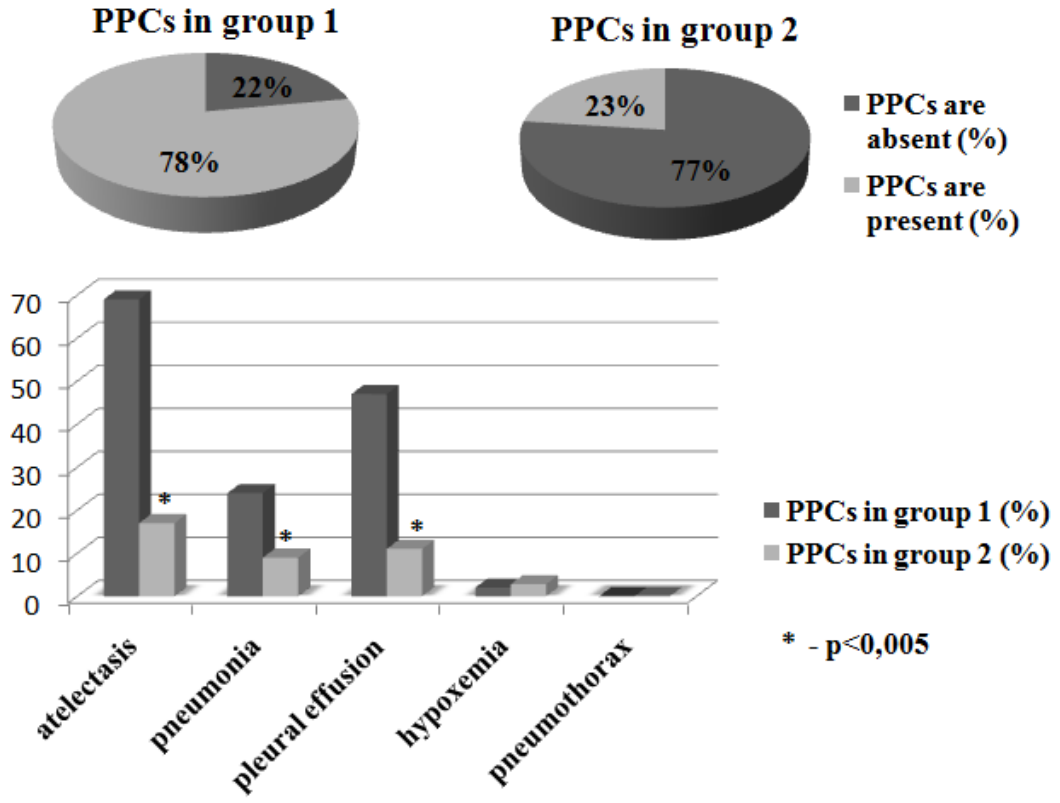

Fig. 1. Comparison of the number of postoperative pulmonary complications in the study groups

A comparison of clinical outcomes showed that patients in group 2 had a significantly lower risk of developing atelectasis in the first week after surgery than patients in group 1: RR 0.2471 (95% CI 0.1276 – 0.4786), p<0.0001; OR 0.0926 (95% CI 0.0345 – 0.2489), p<0.0001. A similar trend was observed about to postoperative pneumonia (RR 0.3482 (95% CI 0.1196 – 1.0139), p=0.0530; OR 0.2875 (95% CI 0.0841 – 0.9833), p=0.0469) and pleural effusion (RR 0.2280 (95% CI 0.0940 – 0.5526), p=0.0011; OR 0.9131 (95% CI 0.0454 – 0.4074), p=0.0004). However, the risk of hypoxemia and pneumothorax in the prospective study group did not decrease in the comparison with the retrospective (hypoxemia: RR 0.3194 (95% CI 0.0134 – 7.6434), p=0.4911; OR 0.03123 (95% CI 0.0124 -7.8682), p=0.4796; pneumothorax: RR 0.9583 (95% CI 0.0194 – 47.3007), p=0.9829, OR 0.9579 (95% CI 0.0186 – 49.3043), p=0.9829).

Discussion. In our work, clinical advantages of using perioperative individualized respiratory support in patients with moderate to high risk of development of postoperative pulmonary complications on the ARISCAT scale are shown, namely a 3.5 - fold decrease in

the total number of PPCs and a significant decrease in the risk and chance of development of atelectasis, pneumonia and pleural effusion. These data coincide with the results of Severgnini et al., who found that in comparison with standard ventilation (TV 9 ml/kg IBW without PEEP), the use of protective ventilation during abdominal operations lasting more than two hours (TV 7 ml/kg IBW with PEEP 10 cm of water and recruiting maneuvers) improves pulmonary parameters in the first five days of the postoperative period, reduces the assessment of the modified clinical scale of pulmonary infections (mCPIS), reduces the level of postoperative pulmonary complications and improves oxygenation [1].

Data from meta-analysis [2] showed that the use of intraoperative protective ventilation (TV 6 ml/kg, PEEP 6-12 cm of water and RM) in patients with intact lungs reduces the risk of developing ARDS, pulmonary infection and atelectasis, but does not affects mortality. Similar results showed another meta-analysis, confirming that protective MV reduces the frequency of PPCs, but does not affect the mortality and duration of stay in ICU and hospital [12]. Meta-analysis [13] showed a decrease in the frequency of postoperative pulmonary infection, atelectasis, acute lung injury and the duration of hospitalization in patients with protective mechanical ventilation compared with standard.

The Cochrane review [14] also showed that intraoperative ventilation with TV10 ml/kg reduces the incidence of postoperative pneumonia and respiratory care, but does not affect the mortality and duration of hospitalization.

In the other large retrospective study, the use of protective intraoperative mechanical ventilation with low TV (6-8 ml/kg) and moderate PEEP (4 cm of water) led to an increase in the 30-day lethality and length of stay in a medical facility, in contrast to standard mechanical ventilation with TV 8-10 ml/kg [15].

Despite the decrease in the number of PPCs using intraoperative protective ventilation, their level remains high in patients with moderate and high risk of PPCs development [16, 17]. It can be assumed that this may be due to the fact that the use of one standard protective strategy is not suitable for all patients.

The authors of the Cochrane Review, published in 2014, concluded that there was not enough data to substantiate the findings of the impact of intraoperative PEEP on lethality and PPCs. Due to the ambiguity of existing data, many researchers are actively developing the idea of an individualized selection of intraoperative PEEP [18].

Uncertainty also exists in the regards to the recruitment maneuvers of the alveoli. In 2015, two meta-analyzes were published, in one of which the frequency of PPCs was independent from the use of alveolar recruiting maneuvers [13]. In the other review, the

authors recommend routine use of the maneuver for recruiting alveoli and PEEP during an intervention to reduce the number of PPCs and improve treatment outcomes [19].

Regarding perioperative physiotherapy, Berman et al. [20] show that breathing exercises aimed at maximizing inhalation efforts, such as IS, are most useful for the prevention of respiratory complications, namely atelectasis and pneumonia. Westwood et al. [21] found a reduction in the level of respiratory complications after major abdominal surgery in patients using incentive spirometers and confirmed that IS helped reduce the length of stay in a hospital.

However, there is another opinion on the effectiveness of the IS, Pantel H et al. [22] did not reveal any influence of IS on the development of PPCs in patients after bariatric surgery, therefore its use is not recommended in this category of patients. Paulo do Nascimento Junior et al. [23] reviewed the data from 12 studies published before August 2013 and concluded that there was evidence of poor quality indicating the lack of efficacy of IS for the prevention of postoperative pulmonary complications in patients after surgery on the upper floor abdominal cavity. This review emphasizes the need for well-designed research in this area.

Conclusions. Perioperative individualized respiratory support in patients with a moderate and high risk of development of postoperative pulmonary complications is an effective method for reducing the number of atelectasis, pneumonia and pleural effusion development after the upper floor of the abdominal cavity open surgical interventions.

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