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APPLICATION OF POSITIVE END-EXPIRATORY PRESSURE (PEEP) IN PATIENTS DURING PROLONGED GYNECOLOGICAL SURGERY

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Abstract. Introduction: *A lot of clinical studies have shown that during prolonged surgery protective ventilation strategy, including low tidal volume, PEEP and recruitment maneuvers (RM) can reduce the rate of postoperative pulmonary complications, which are the second most common cause for postoperative mortality. Therefore, it is important to investigate clinical methods for preventing them. The strategy of protective ventilation is easy and safe for the patients and inexpensive for application during prolonged surgery.* ***Aims:*** *The objective of this trial was to study whether application of PEEP in patients during prolonged gynecological surgery could decrease the postoperative complications.* ***Material and Methods:*** *We compared the rates of postoperative complications in patients after prolonged open gynecological surgery, who were divided into 2 groups – group A, which was the control group on non-protective ventilation (35 patients) and group B on protective ventilation (35 patients). The patients in the control group were ventilated with tidal volume (VT) of 8-10 ml/kg without PEEP and RM; the patients in group B were ventilated with VT = 6-8 ml/kg according to their Predicted Body Weight, with a PEEP of 6 cm H_2O and RM, which consisted of applying continuous positive airway pressure of 30 cm H_2O for 30 seconds. RM was performed after intubation, after every disconnection from ventilator and before extubation. The study was successfully performed without a need for a change in the type of ventilation strategy because of hypoxia or hemodynamic instability. Statistical nonparametric test (e.g. chi- square) was applied.* ***Results:*** *Total rate of all postoperative complications observed in both groups was 27,1%. We found a significant relationship between application of PEEP and lower rates of postoperative pulmonary complications in group A (39,4%) compared to group B (12,1%), lower rate of respiratory failure (33,3% in group A vs. 9,1% in group B -) and atelectasis (21,2% in group A vs. 0% in group B).* ***Conclusion:*** *The protective ventilation strategy (low VT, PEEP and RM) in patients during prolonged gynecological surgery can reduce the rate of postoperative pulmonary complications such as respiratory failure and atelectasis.*

Key words: *PEEP, RM, low VT, protective ventilation, postoperative pulmonary complications*

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INTRODUCTION

General anesthesia with muscle relaxation and supine position can decrease functional residual capacity [1, 2] and lead to collapse of alveoli in the lung`s bases. This results in perfusion without ventilation in these segments of the lung – the zones of atelectasis [3, 4], where left-to-right shunt increases leading to hypoxia [4, 5]. In fact, the application of positive end-expiratory pressure (PEEP) in patients during general anesthesia in the end of expiration prevents the alveoli from collapsing and atelectasis [3, 4]. The use of a recruitment maneuver (RM) can open the alveoli, which were previously collapsed [6]. According to some randomized studies the intraoperative application of PEEP can reduce the number of patients who develop postoperative atelectasis and hypoxia [7, 8, 9, 10, 11, 12, 13]. Studies showing that postoperative pulmonary complications as pneumonia, respiratory failure, etc. also decrease are scarce.

Mechanical ventilation with high tidal volume in patients without any pulmonary diseases can lead to volume associated trauma of the lung [14]. But ventilation with a low tidal volume without application of PEEP can cause atelecto-trauma, because of cycle opening and closing of alveoli during the respiratory cycle. Ventilation-induced lung injury (VILI) can also include bio-trauma, which is defined by increased level of pulmonary and systemic inflammatory factors in mechanically ventilated patients [15, 16]. The strategy of protective ventilation includes low tidal volume and application of PEEP together with RM [17, 18]. The level of optimal PEEP is a matter of controversy because of its negative effect on the patient`s hemodynamics [19].

AIMS

The objective of this study was to investigate the effect of positive end-expiratory pressure (PEEP), which is applied together with recruitment maneuver (RM) and low tidal volume (calculated with Predicted Body Weight) in patients undergoing prolonged gynecological operations (lasting more than 2 hours), on the frequency of postoperative complications.

We hypothesized that the application of PEEP in patients during prolonged gynecological surgery would decrease the rate of postoperative pulmonary complications.

MATERIAL AND METHODS

In this prospective cohort study from November, 2016 to May, 2017 we followed 70 patients, who fulfilled the inclusion criteria: adult patients – over 18 years; non pregnant women; patients undergoing non-laparoscopic open gynecological operations, lasting more than 2 hours.

Patients were excluded from the study if they met one of the exclusion criteria: patients who have been mechanically ventilated the last month before surgery and patients with previous pulmonary surgery; patients with severe chronic obstructive pulmonary disease (COPD), requiring non-invasive ventilation with CPAP (continuous positive airway pressure) masks, oxygen therapy or systemic corticosteroid therapy; patients with morbid obesity-body mass index < 40 kg/m^2; hemodynamically unstable patients – these ones with acute coronary syndrome, persistent ventricular tachycardia, heart failure – NYHA IV; in case of emergency surgery; patients with neuromuscular diseases.

We used data from preoperative consultations with specialists in anesthesiology and internal medicine, data from preoperative laboratory tests, imaging studies and other specialized consultations to determine ASA and ARISCAT score. The last one can be used as predictive factor for development of postoperative complications [19]. We calculated ARISCAT score using the following criteria: open gynecological operations – 15 points (p.); patient`s age – under 50 years – 0 p., from 51 to 80 years – 3 p., over 80 years – 16 p.; preoperative saturation – over 96% – 0 p., from 95% to 91% – 8 p., under 90% – 24 p.; respiratory infection during last month – 17 p.; preoperative anemia – 11 p.; expected duration of operation less than 2 hours – 0 p., from 2 to 3 hours – 16 p., over 3 hours – 23 p.

The selected patients were divided in 2 groups: control group (group A) – in which non-protective strategy of mechanical ventilation was used – tidal volume (Vt) – 8-10 ml/kg, without PEEP, RM; exposed group (group B) – in which protective strategy of mechanical ventilation was used – PEEP – 6 cm H_2O with RM, low Vt – 6-8 ml/kg, which was calculated according to the patient`s Predicted Body Weight (PBW). We used the following formula for calculating PBW for women:

– 45,5 + 0,91*(heigh – 152,4).

The Recruitment maneuver (RM) consisted of use of continuous positive airway pressure (CPAP) = 30 cm H_2O for 30 s. It was performed after intubation, after each disconnection of the patient from mechanical ventilation, and before extubation. The purpose of this maneuver is to expand alveoli which have been already collapsed. On the other hand, the application of PEEP aims at preventing the alveoli from collaps-

ing. RM was not performed in hemodynamically unstable patients, because it decreases cardiac output. In both groups we used Volume Control Mechanical Ventilation, respiratory rate = 10-14/min and inspiration: expiration ratio- I:E-1:2, Fio2 = 0.6. We used the method of side stream spirometry in order to determine peak inspiratory pressure (Ppeak) and plateau pressure (Pplat.), pulse oximetry to determine saturation(SpO_2), capnometry for estimating end expiratory CO_2 concentration ($EtCO_2$), ECG monitoring and a non-invasive methods formeasuring systolic blood pressure (SBP), mean blood pressure (MBP) and diastolic blood pressure (DBP). The total dose of vasopressors used – ephedrine, noradrenaline, adrenaline, also the amount of infused crystalline and colloidal solutions, freshly frozen plasma and erythrocyte concentrate during the operations, were calculated. Intraoperative blood loss and diuresis were also measured. Postoperative laboratory tests like complete blood count, hemostasis, blood biochemistry – glucose, urea, creatinine, liver enzymes, total protein, albumin, electrolytes, arterial blood gas analysis were analyzed. The study was successfully performed without a need for a change in the type of ventilation strategy because of hypoxia or hemodynamic instability. The participants were followed for a period of 5 postoperative days for development of pulmonary and extra-pulmonary complications. Pulmonary complications included respiratory failure; pneumonia; acute respiratory distress syndrome (ARDS); atelectasis; pulmonary edema; bronchospasm; pneumothorax; pleural effusion; application of non-invasive ventilation with CPAP masks. Extra-pulmonary complications included sepsis, severe sepsis, septic shock; anastomosis insufficiency; acute renal failure; acute myocardial infarction; new atrial fibrillation; bleeding from gastrointestinal tract. Diagnosis was based on symptoms as fever, tachypnea, dyspnea, cough with sputum, physical examination – wheezing, weak breathing in the lung bases etc., laboratory tests, imaging exams.

Statistical considerations: According to the null hypothesis there should be no statistically significant association of the use of PEEP in patients during prolonged gynecological operations with the rate of postoperative complications. This hypothesis was verified by the crosstab method, analyzing the frequencies of each complication in both groups. The observed frequencies (rates) were presented as percentages. The level of significance was set at $p \leq 0,05$. The nonparametric chi- square test was applied.

RESULTS

The total rate of all postoperative complications in both groups was 27.1% (Tabl. 1). The null hypothesis was rejected and a significant relationship between the application of PEEP and lower rates of postoperative complications such as respiratory failure, atelectasis, need for non-invasive ventilation with CPAP masks, was registered. However, this study didn`t prove any statistically significant relationship between the application of PEEP during prolonged gynecological operations and the frequencies of postoperative pneumonia, bronchospasm, pleural effusion, extra-pulmonary complications. In this study there weren`t any cases of pneumothorax, pulmonary edema, pulmonary thromboembolism.

Table 1. Postoperative pulmonary complications in both groups

	Patient number	Percent %
None	51	72,9
Pulmonary complication	19	27,1

The percent of pulmonary postoperative complications in the control group A was 39,4% and it was 12,1% in group B (Table 2).

Table 2. Postoperative pulmonary complications in each group

Type of group		None	Pulmonary complication	Total
Control group – PEEP = 0 cm H_2O	N	20	13	33
Control group – PEEP = 0 cm H_2O	%	60,6%	39,4%	100,0%
Exposed group – PEEP = 6 cm H_2O	N	29	4	33
Exposed group – PEEP = 6 cm H_2O	%	87,9%	12,1%	100,0%
Total	N	51	19	70
	%	72,9 %	27,1%	100,0%

Abbr.: PEEP-positive end – expiratory pressure

The rate of postoperative pulmonary complications in the control group A (PEEP – 0 cm H_2O) was significantly higher compared to the rate of these complications in the exposed group B (PEEP – 6 cm H_2O) .

The percent of patients who developed postoperative atelectasis was 21,2% in group A and 0,0% in group B (Table 4).

Table 5 shows the occurrence of atelectasis in both groups.

Table 3. Statistical chi-square test for cases of pulmonary complications

		Chi-Square Tests			
Pearson Chi-Square	7,327a		Value		0,026
Likelihood Ratio	7,682	2			,021
Number of Valid Cases	70				

Table 4. Ocurrence of atelectasis in each group

		Not observed	Observed	Total
Group A, control group (Peep – 0 cm H_2O)	N	26	7	33
	%	78,8%	21,2%	100,0%
Group B (Peep – 6 cm H_2O)	N	33	0	33
	%	100,0%	0,0%	10, 00%
Total	N	62	8	70
	%	88,6%	11,4%	100,0%

Abbrev.: PEEP = positive end–expiratory pressure

Table 5. Statistical chi-square test for atelectasis

	Value	Degree of freedom	Asymptotic significance (2-sided)
Pearson Chi-square	8,106	2	0,017
Likelihood ratio	11,149	2	0,004
Number of valid cases	70		

The rate of observed postoperative atelectasis was significantly higher in the control group A compared to the active group.

The percent of patients who developed postoperative respiratory failure in group A was 33,3% and in group B was 9,1% (Table 6).

Table 6. Rates of patients with respiratory failure in both groups

	Not observed	Observed	Total	
Control group (group A, Peep – 0)	N	22	11	33
	%	66,7%	33,3%	100,0%
Group B (peep-6)	N	30	3	33
	%	90,9%	9,1%	100,0%
Total	N	54	16	70
	%	77,1%	22,9%	100,0%

PEEP – positive end-expiratory pressure

The rate of the cases of observed postoperative respiratory failure was significantly higher in the control group compared to the other group.

Table 7. The Chi-square test for cases of respiratory failure

	Value	Degree of freedom	Asymptotic significance (2-sided)
Pearson Chi-square	7,272	2	0,026
Likelihood ratio	7,595	2	0,022
Number of valid cases	70		

Effects of PEEP on intraoperative hemodynamic stability of patients (intraoperative SBP, MBP, DBP, Ppeak, Pplat and the amount of infused crystalline or colloidal solutions, the dose of used vasopressors, saturation and bleeding).

The application of PEEP – 6 cm H_2O does not change in a significant way the intraoperative values of SBP, MBP, DBP, Ppeak, Pplat and also the amount of infused crystalline or colloidal solutions, the dose of used vasopressors, saturation and blood loss.

Table 8 below displays the mean values of ASA, duration of operation, ARISCAT score, crystalline and colloidal infusions, dose of ephedrine, blood loss.

Table 8. Mean values of ASA score, operation duration time, ARISCAT score, infusion volume, dose of ephedrine, bleeding

		American society of anesthesiologists score (ASA)	Operation duration time	ARISCAT score	Infusion volume	Ephedrine dose	Blood loss
Peep – 0	Mean	2,79	2,9500	37,45	2430,30	5,61	909,09
	Number	33	33	33	33	33	33
	Standard Deviation	0,696	0,77701	5,922	825,562	9,743	837,915
Peep – 6	Mean	2,73	2,8621	37,15	2224,24	4,84	733,33
	Number	33	33	33	33	32	33
	Standard Deviation	0,626	0,73261	5,397	640,815	11,742	458,712
Total	Mean	2,79	2,9200	37,19	2332,86	5,07	828,57
	Number	70	70	70	70	69	70
	Standard Deviation	0,657	0,73165	5,504	728,851	10,449	657,210

PEEP – positive end-expiratory pressure

Most of the patients in this study were estimated as ASA 3 – 52,9%, as ARISCAT score – 34 p. – 51,4%. The duration of the surgical procedure was usually 2 h 30 min, intraoperative blood loss – 1000 ml – 18%.

DISSCUSION

This study proves the hypothesis according to which the application of PEEP – 6 cm H_2O together with RM, and low Vt (calculated on PBW) during gynecological surgery lasting longer than 2 hours decreases the rate of postoperative pulmonary complications. Pulmonary complications are the second most common cause for postoperative mortality. So it is necessary to look for ways to reduce them. In this study we used PEEP at a constant level of 6 cm H_2O, which protects the alveoli from collapsing. On the other hand, RM re-expands the alveoli which have already collapsed. This double effect of PEEP and RM should theoretically prevent the development of postoperative atelectasis. The clinical importance of atelectasis is related to the risk of development of respiratory failure. Our study proves statistically significant lower rate of the cases of postoperative atelectasis and respiratory failure in the lung-protective ventilation group. We didn`t observe statistically significant effect of the application of PEEP at a level of 6 cm $H_2O$ on the patients' hemodynamics, the amount of crystalline and colloidal infusions, or the dose of vasopressors used. There weren`t cases of barotrauma and pneumothorax.

In our study we didn`t estimate separately the effect of PEEP and low tidal volume on the rate of postoperative pulmonary complications. Some randomized studies also have the same limitation [17, 18, 19, 20]. According to randomized studies, the strategy of protective ventilation-low tidal volume, in combination with PEEP and RM decreases the rate not only of postoperative atelectasis, but also of postoperative respiratory failure, ARDS, non-invasive ventilation with CPAP masks, re-intubation and postoperative mechanical ventilation [17, 18]. In the group exposed to protective ventilation these studies proved a shorter hospital and intensive care unit stay and lower mortality rate also compared to control groups [7, 18]. The optimal level of PEEP used intra-operatively in patients without preoperative lung injury is controversial [19]. The high level of PEEP – 12 cm H_2O in patients with healthy lungs applied during prolonged surgeries causes more frequently intraoperative hypotension and increased the doses of used vasopressors, but didn`t decrease the rate of postoperative complications [19]. Some randomized studies tried to predict preoperatively the risk for postoperative complications using the ARISCAT score [18, 19, 20]. This score can define the patients in whom the strategy of protective mechanical ventilation may reduce the postoperative complications.

The pulmonary postoperative complications can prolong a patient`s hospital stay and increase its price. According to some randomized studies general anesthesia with mechanical ventilation applied to patients with healthy lungs during prolonged surgery leads to ventilator-induced lung injury (VILI). Many multicenter randomized trials try to discover the safest and most effective strategy of intraoperative mechanical ventilation. Their principal aim is to reduce postoperative pulmonary and extra-pulmonary complications. Agreement on the parameters of protective ventilation – the measure of tidal volume, level of PEEP, application of RM has not yet been achieved. There is not clear evidence if only low tidal volume without PEEP or PEEP without low tidal volume or the both parameters decrease postoperative pulmonary complications.

CONCLUSION

We conclude that the use of protective ventilation strategy – low tidal volume, application of PEEP at level 6 cm H_2O and RM, can reduce the cases of postoperative pulmonary complications as atelectasis, respiratory failure and application of non – invasive ventilation with CPAP masks. In our study there is no significant difference between intraoperative haemodynamic parameters of patients in both groups and also of doses of used vasopressor and quantity of infused crystalline and colloidal solutions. In conclusion, the investigated strategy of protective ventilation is easy for application, effective and safe for the patients.

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