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ORIGINAL RESEARCH **PERIOPERATIVE MEDICINE**

Early postoperative arterial hypoxemia can predict postoperative pulmonary complications

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Abstract

Background & Objective: Postoperative hypoxemia is very common but not unavoidable. It can lead to pulmonary complications through a variety of routes. This study was designed to evaluate changes in arterial blood gases in the initial days after abdominal surgery and to identify the risk factors for postoperative arterial hypoxemia and the prognostic value of arterial hypoxemia to predict pulmonary complications.

Methodology: 215 consecutive patients undergoing laparotomies under general anesthesia with intubation, age ≥ 18 y, ASA I, II, were enrolled under convenient sampling. The patients with severe preoperative disease, e.g., heart failure grade 3 or 4; liver cirrhosis; kidney failure; or COPD were excluded. One day before the surgery, the spirometric values of the patients were measured. Arterial blood sample (T0) for gas analysis was ontained. Anesthesia technique consisted of midazolam, fentanyl, propofol, esmeron, intubaion and epidural catheter. Patients were monitored in the recovery room for signs of lung complications, VAS pain score, X-ray, blood assessment, and sputum culture if indicated. Arterial blood gas was re-tested after 24 h (T1) and 48 h (T2). The criterion for the diagnosis of arterial hypoxemia was $PaO_2/FiO_2 < 300$.

Statistical nalysis done in SPSS software (version 16.0). Data presented as mean ± SD or n (%). Student's t-test, paired t-test and ANOVA test were used as required. Statistical significance was set at $P < 0.05$.

Results: On the first and second days after surgery, both PaO_2 and PaO_2/FiO_2 decreased significantly compared to the preoperative values. 14 and 30 patients on the first and second day after surgery, respectively had decreased arterial blood oxygen levels. All patients who had hypoxemia on the first day after surgery suffered from hypoxemia on the second day. Decreased arterial blood oxygen level on the second day after surgery is a predictor of postoperative respiratory complications. After the first day of surgery, a Tiffeneau-Pinelli index ≤ 75%, $A–aO_2 \geq 20$, and anesthesia duration ≥ 150 min were independent risk factors for arterial hypoxia, whereas after day 2, these were a Tiffeneau-Pinelli index ≤ 75%, $A–aO_2 \geq 20$, fluid balance ≥ 1700 ml and preoperative upper respiratory tract infections.

Conclusion: Postoperative arterial hypoxemia on the second day was a prognostic index for postoperative pulmonary complications. Independent risk factors for hypoxemia were identified.

Key words: Postoperative pulmonary complications; Hypoxemia; PaO_2/FiO_2 ratio; Tiffeneau-Pinelli index; $A–aO_2$

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1. Introduction

Postoperative pulmonary complications are the leading cause of mortality and morbidity after surgery, especially in abdominal surgery. The rate of pulmonary complications after surgery varies from 1% to 23%, depending upon the study and the diagnostic criteria used.[1] According to Finlay, the pulmonary complication rate is 32% in patients with upper abdominal surgery, 16% in lower abdominal surgery, and 30% in thoracic surgery. Pulmonary complications prolong the duration of hospital stay; on an average, patients with pulmonary complications stay in the hospital for 28 days compared to 4 days without complications. The mortality rate within 30 days is also increased, with 0.2%–3% in patients without complications, but 14%–30% in patients with pulmonary complications.[1]

Table 1: Classification of the degree of hypoxemia

Parameter	Value	Degree
PaO_2/FiO_2	≥ 300	0
	225 – 299	I
	175 – 224	II
	100 – 174	III
	< 100	IV

Pulmonary function after surgery is affected by many factors such as anesthesia induction method, the duration of anesthesia, procedure, surgical site, or patient's general condition. 2 This indicates that postoperative hypoxemia is almost unavoidable. Mild or moderate arterial hypoxemia is not dangerous; however, if this condition persists or appears briefly in patients with pre-existing organ dysfunction, the problem becomes more severe and can lead to organizational hypoxia or multiple organ failure. Not all patients with arterial hypoxemia undergo pulmonary complications. However, all pulmonary complications cause arterial hypoxemia, with or without CO2 elevation.

Thanks to arterial blood gas measurement, doctors can ascertain whether the patient has reduced arterial oxygen based on the PaO2/FiO2 ratio 3 and the association between preoperative arterial hypoxemia and postoperative pulmonary complications are observable. 4 However, the correlation between postoperative pulmonary complications and hypoxemia in the early postoperative period, when the patient has no real pulmonary failure due to residual anesthetic drugs is still lacking. This study was designed to evaluate the changes in arterial blood gases in patients during the initial days after abdominal surgery, to identify the risk factors for postoperative arterial hypoxemia and the prognostic value of arterial hypoxemia to predict pulmonary complications.

2. Methodology

Following approval of the study protocol by the Institutional Review Boards, 215 consecutive patients, who underwent surgery, were enrolled in this study over a period of two years. Patient characteristics, assessed prior to surgery, included age, sex, smoking habits, breathlessness, body mass index, spirometric variables, and preoperative arterial blood gases.

2.1 Inclusion Criteria

The inclusion criteria were; patients undergoing abdominal surgery under general anesthesia with intubation, age ≥ 18 y, ASA I and II, and patients without severe preoperative disease such as: heart failure grade 3 or 4, liver cirrhosis Child–Pugh classes B and C, kidney failure, and COPD stages C and D.

2.2 Exclusion criteria

The exclusion criteria were as follows; the patient refusal to participate in the study, any contraindication to anesthetics, analgesics, muscle relaxants and epidural anesthesia, a severe cardiovascular condition (e.g., NYHA > II), the patient needs to be ventilated for more than 24 h after surgery and insufficient data.

2.3 Procedure

Pre–anesthesia consultation was performed 1 d before the surgery. The spirometric parameters of the patients were measured (Spirometer HI-801, Japan). On the next day, in the operating room, a peripheral venous line was inserted and inj. midazolam 0.04 mg/kg was administered. Arterial blood was collected for the first blood gas analysis (T0). Epidural catheters were placed in all patients for postoperative pain relief. The anesthesia protocol was as follows: fentanyl 2 µg/kg, propofol 1–2 mg/kg, esmeron 0.6–1 mg/kg, and maintenance with servofluran.

After surgery, patients were monitored in the recovery room for signs such as cough, shortness of breath, temperature, lung auscultation, and VAS pain scores. Chest X-ray, blood assessment, and sputum culture were indicated when respiratory complications were suspected. Arterial blood gases were re-tested after 24 h (T1) and 48 h (T2). The criterion for the diagnosis of arterial hypoxemia was a $PaO_2/FiO_2 < 300$.

Criteria for the diagnosis of postoperative pulmonary complications

A positive diagnosis was determined when at least four of the following symptoms appeared; [5]

Chest X-ray showing atelectasis or consolidation

Continuous fever over 38 °C for at least one day after surgery

SpO_2 < 90% for at least one consecutive day after surgery

Yellow or green sputum, different from that before surgery

Bacterial sputum culture showing bacterial growth

Unexplained nlood culture or specific antibiotics needed to be prescribed due to respiratory infections

Abnormal lung sounds audible, or heard on aucultation, different from those before surgery

Diagnosis of postoperative pulmonary complications by specialist doctors

2.4 Statistical analysis

The data were collected and processed using SPSS software (version 16.0). Descriptive figures are presented as mean ± SD or n (%). For quantitative variables, the difference was calculated using the Student's t-test to compare the means of the two groups; paired t-test was used to compare two average values of a group; ANOVA test was used to compare three average values or more. Statistical significance was set at P < 0.05. Qualitative variables were processed using the χ^2 test.

The risk factors were selected and analyzed through two steps: first, univariate analysis was used to identify risk factors with P < 0.05; second, multivariate analysis was performed using univariate analysis. The risk factors were selected with P < 0.05, then applied to the logical regression equation by the forward conditional method to identify toxic risk factors and OR correction was calculated.

3. Results

The number of recruited patients was 215, including 108 males (50.2%) and 107 females (49.8%). The mean age was 56.36 ± 12.02 (24-85) y, of which 138 (64.2%) patients were over 60 y, and 77 (35.8%) patients were under 60 y. 7 (3.3%) patients had upper pulmonary infections. The mean Tiffeneau-Pinelli index was 81.49 ± 9.23%. 44 (20.47%) patients had obstructive ventilation, mainly stage I (43/44 patients).

After surgery, PaO_2 and $PaO_2/FiOs$ decreased significantly compared to that before surgery. On the first day after surgery, 14 (6.5%) patients had hypoxemia; whereas, on the second day after surgery, the number of patients with hypoxemia increased to 30 (13.95%) (Table 2). 16 out of 30 patients were diagnosed with hypoxemia after 2 days of pulmonary complications; e.g., bronchitis in 12 and atelectasis in 4 patients. Pulmonary embolism occurred in one patient without hypoxemia on day 3.

The prognostic value of arterial hypoxemia for postoperative pulmonary complications is shown in Table 3. The sensitivity and specificity were 94.12% and 92.93%, respectively. In addition, the positive and negative predictive values were 53.33% and 99.46%,

Table 2: The change in blood gas after surgery compared with before surgery

Parameters	Before surgery (T0)	After surgery 24 h (T1)	After surgery 48 h (T2)
PaO_2	89.38 ± 13.50	83.81 ± 17.10*	77.59 ± 12.65*
PaO_2/FiO_2	420.82 ± 56.41	392.05 ± 72.47*	363.31 ± 60.73*
$PaCO_2$	39.19 ± 4.09	39.43 ± 4.14	39.27 ± 3.98
$A–aO_2$	16.41 ± 10.50	23.66 ± 14.24*	28.04 ± 15.93*

*Data presented as Mean ± SD; * P < 0.05*

Table 3: Arterial hypoxemia and pulmonary complications after surgery

	Complications	No complications	All
Arterial hypoxemia	16	14	30
No arterial hypoxemia	1	184	185
All	17	198	215

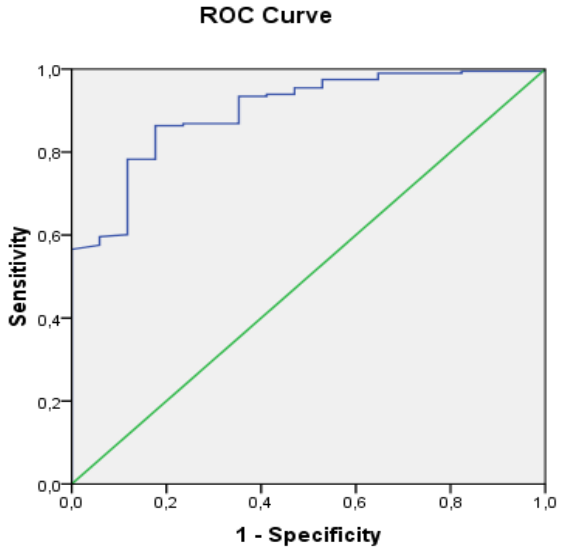

Figure 1: ROC curve for arterial hypoxemia and pulmonary complications after surgery

respectively, indicating the reliability of this prognostic value.

The area under the ROC curve was 0.899, suggesting that early arterial hypoxemia is a reliable indicator of the prognosis of pulmonary complications after abdominal surgery with a threshold of PaO_2/FiO_2 at 300 (Figure 1).

The investigation of risk factors was done for the parameters for 1 and 2 days after surgery (Tables 4 & 5). A Tiffeneau-Pinelli index ≤ 75% was the strongest independent risk factor for hypoxemia after the first day of surgery (OR = 5.13), whereas preoperative upper respiratory tract infection was the strongest after day 2 (OR = 48.86).

4. Discussion

In our study, the PaO_2 was reduced to 83.81 ± 17.10 mmHg one day after surgery and further decreased to 77.59 ± 12.65 mmHg two days after surgery ($P < 0.05$). This result suggests that pulmonary function decreased quite soon after surgery, even when the anesthetic drugs were completely eliminated. Similarly, the PaO_2/FiO_2 ratio was also lower after surgery than before surgery ($P < 0.05$).

The postoperative pulmonary complications diagnosed in a majority of patients are bronchitis or atelectasis. Sixteen of the 30 patients with complications were diagnosed with hypoxemia after surgery on the second day (53.33%). The arterial hypoxemia after day 2 can be an objective sign and a good prognostic factor for postoperative pulmonary complications with an area under the ROC curve of 0.899. This study is the first to show this prognosis in patients undergoing abdominal surgery.

The Tiffeneau-Pinelli index was found to be the most influential risk factor for postoperative hypoxemia. According to Gerald et al., if the patient has a preoperative ventilation disorder, the postoperative disorder is higher than in the normal group.6 In our study, preoperative restrictive ventilation disorder was not a risk factor for the postoperative mechanical disorder, but preoperative obstructive ventilation disorder was a risk factor for postoperative hypoxemia (OR on the first day: 4.43; OR on the second day: 2.67, $P < 0.05$).[7,8] However, other studies have suggested that postoperative pulmonary function measurement might not be a critical criterion, because patients with poor ventilation function are still manageable with an acceptable risk of pulmonary complications. Clinical examination is considered to play a more important role.

The pulmonary artery alveolar oxygen gradient might not be the gold standard to determine the degree of atelectasis after surgery, but it could indirectly assess the level of a shunt in the lungs. $A–aO_2$ is increased when a patient has a pulmonary shunt or perfusion dysfunction when

Table 4: Independent risk factors for arterial hypoxemia 1 day after surgery

Risk factors		PaO_2/FiO_2		p	OR (95% CI)
		≤ 300	> 300		
Tiffeneau-Pinelli index	≤ 75	7	37	0.007	5.13 (1.56 – 16.87)
	> 75	7	164		
$A–aO_2$	≥ 20	9	62	0.022	4.01 (1.23 – 13.21)
	< 20	5	139		
Anesthesia duration (min)	≥ 150	8	58	0.016	4.35 (1.32 – 14.36)
	< 150	6	143		

Table 5: Independent risk factors for arterial hypoxemia 2 days after surgery

Risk factors		PaO_2/FiO_2		P	OR (95% CI)
		≤ 300	> 300		
Tiffeneau-Pinelli index	≤ 75%	11	33	0.047	2.65 (1.01 – 6.95)
	> 75%	19	152		
Preoperative upper respiratory tract infections (n)	Yes	6	1	0.001	48.86 (5.27 – 453.42)
	No	24	184		
$A–aO_2$	≥ 20	16	55	0.008	3.32 (1.37 – 8.03)
	< 20	14	130		
Fluid balance (mL)	≥ 1700	9	27	0.024	3.23 (1.17 – 8.97)
	< 1700	21	158		

associated confounders such as age or FiO_2 have been eliminated. Our results demonstrated that the postoperative $A–aO_2$ significantly increased compared to that before surgery ($P < 0.001$), indicating that the degree of the pulmonary shunt is greater or the risk of hypoxemia is higher.[9,10] Preoperative $A–aO_2 \geq 20$ is a risk factor for arterial hypoxemia after surgery both after 1 and 2 days with OR of 4.01 and 3.32, respectively.

Considering preoperative upper respiratory infections, our results showed that inflammation of the upper respiratory tract caused arterial hypoxemia after surgery on the second day (6 out of 7 patients) with $P < 0.01$ and OR = 46. These patients had pulmonary complications in the form of bronchitis on postoperative days 3 and 4. This suggests the role of preoperative respiratory diseases and preoperative clinical examinations in avoiding postoperative complications.[10]

The duration of anesthesia affects hypoxemia after surgery. Four multi-center studies concluded that anesthesia duration of more than 3 h increased the risk of hypoxemia by 2.14 times compared with the group with short anesthesia. This could be explained by the long mechanical ventilation disturbing the moving hair-cell in the airway, resulting in the protective function and gas exchange of the alveolar membrane.[11-14]

Lastly, infusion therapy is a very important part of patient care before, during, and after surgery. The volume of the fluid balance depends on the individual and type of surgery. In multivariate analysis, we found that fluid balance ≥ 1700 ml was a risk factor for hypoxemia 2 days after surgery, with an OR of 3.23. Therefore, controlling and limiting infusions during surgery is necessary.

5. Recommendations

Based on our results, we would like to suggest:

(1) To maximize the management of potential preoperative risk factors related to hypoxemia and postoperative respiratory complications, such as chronic lung diseases and acute upper respiratory tract conditions.

(2) Eliminate and minimize risk factors during and after surgery for postoperative hypoxemia: (a) an appropriate strategy for anesthetic resuscitation and intravenous infusion in order to be able to extubate as soon as possible, (b) coordinate well between the anesthesiologists and the surgeons to minimize surgery time, (c) plan for postoperative analgesia and prevent postoperative thrombosis prophylaxis so that patients can cough well, spit-up sputum, and avoid vascular complications.

(3) Preoperative blood gases should be indicated when the patient has real ventilation disorders when measuring respiratory function.

(4) Further research on elderly and malnourished patients (albumin ≤ 35 g/dl) is needed to assess the true role of these risk factors.

6. Conclusions

On the first and second days after surgery, blood oxygenation parameters such as PaO_2 and PaO_2/FiO_2 decrease significantly compared to those before surgery. Postoperative arterial hypoxemia on the second day is a prognostic index for postoperative pulmonary complications with high sensitivity, specificity, positive and negative values. The independent risk factors for hypoxemia are the long duration of anesthesia, preoperative upper respiratory tract infections, preoperative obstructive ventilation disorder, $A–aO_2 > 20$, and extensive intraoperative fluid infusion.

7. Conflict of Interest

Authors declare no conflict of interest. No external funding was involved in the study.

8. Author Contributions

MQP: Concept, conduct of study work, supervision

HMB: Conduct of study, result analysis, manuscript editing

TTPT: Result analysis, manuscript writing

THN: Conduct of study, result analysis, manuscript editing, supervision

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