



Arterial Blood Gas Analysis as a Prognostic Indicator in Acute Pulmonary Embolism

Eugerta Dilka^{1,2}

Edmond Puca³

Sofjela Telo²

Leonard Berisha⁴

Serxho Golgota²

¹Department of Internal Medicine, Faculty of Medicine, University of Medicine, Tirana, Albania

²Regional Hospital Center "Shefqet Ndroqi", Tirana, Albania

³Service of Infectious Diseases, University Hospital Center, Tirana, Albania

⁴Tropoja District Hospital, Tropoja, Albania

Received: 13 March 2026 | Accepted: 10 June 2026 | Published: 23 July 2026

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DOI: 10.56345/ijrdv13n240

Abstract

Background: Acute pulmonary embolism (PE) is a potentially life-threatening condition that requires accurate risk stratification. In patients with PE the prognostic value of arterial blood gas (ABG) abnormalities remains controversial. **Aim:** To assess the prognostic value of ABG parameters and their association with established prognostic indicators such as the Pulmonary Embolism Severity Index (PESI), pro-B-natriuretic peptide (pro-BNP) levels, blood pressure status, and thrombus localization on contrast-enhanced computed tomography pulmonary angiography (CTPA). **Methods:** This retrospective study included 83 hospitalized patients with acute pulmonary embolism (PE) confirmed by CTPA during 2023. Demographic characteristics, ABG parameters, laboratory findings, PESI score, hemodynamic status and thrombus localization were collected from records at admission. Patients were divided into survivor and non-survivor groups based on in-hospital outcomes. Logistic regression and correlation analyses were performed using SPSS version 26.0. Statistical significance was defined as $p < 0.05$. **Results:** The mean age of the patients was 69.3 ± 11.2 years, and 56.6% of patients were female. Hypocapnia (69.9%) and alkalemia (42.2%) were common findings. Most ABG parameters did not differ significantly between survivor and non-survivor. Although all patients presenting with acidemia ($pH < 7.35$) died during hospitalization, this finding was not statistically significant due to the small number of cases. Lower (more negative) base excess values were an independent predictor of mortality ($OR=0.82$, $p=0.014$). The PESI score was significantly higher in non-survivors than in survivors ($p < 0.001$) and emerged as the strongest predictor of in-hospital mortality. **Conclusions:** Most ABG parameters were not independent predictors of in-hospital mortality. However, acidemia and negative base excess may help identify patients at increased risk and provide complementary prognostic information. The PESI score remained the strongest predictor of mortality. More large studies are needed to better understand the role of ABG in predicting outcomes in acute PE.

Keywords: pulmonary embolism, ABG analysis, mortality

1. Introduction

Pulmonary embolism (PE) is a potentially life-threatening condition that remains challenging in contemporary clinical practice. It is characterized by the obstruction of blood flow in the pulmonary arteries or their branches, primarily due to thrombotic material, resulting in substantial morbidity and mortality (Coon, 1959; Faluk, 2021; Humbert, 2022; Neumann, 2020). Globally, PE is the third leading cause of cardiovascular-related deaths, after coronary artery disease and stroke (Raskob, 2014). In acute PE, respiratory effects include increased alveolar dead space, hypoxemia, hyperventilation. Arterial hypoxemia is a common, although not universal, finding in patients with acute embolism. Pulmonary infarction is an uncommon consequence because of the bronchial arterial collateral circulation (Ouellette, 2024). In patients with pulmonary embolism, the typical findings of the ABG analysis are: hypoxemia, hypocapnia, increased alveolar-arterial oxygen difference (alveolar-arterial gradient), respiratory alkalosis (Cvitanic, 2012). Some variations include: hypercapnia in cases of massive PE secondary to circulatory collapse, normal PaO₂, normal alveolar-arterial oxygen gradient, combined respiratory and metabolic acidosis in cases of massive PE (Stein 1996). High-risk pulmonary embolism has been defined by hemodynamic parameters and evidence of myocardial injury rather than anatomic findings because the former is associated with adverse outcomes (Konstantinides, 2019). The 2014 ESC guidelines included the advanced risk stratification of PE patients with PESI I-III (Konstantinides, 2014), but the clinical implications of prognostic assessment and therapeutic strategy in these patients still warrant further investigation, because mortality in hemodynamically stable patients remains unknown (Cvitanic, 2012; Volschan, 2009; Clark, 2013; den Exter, 2013; Taylor, 2013).

2. Methods

This retrospective study included 83 hospitalized patients with acute PE during 2023. PE was confirmed by CTPA. Patients with incomplete medical records or missing admission ABG measurement were excluded from the analysis. We collected data from electronic medical records, including patient characteristics, comorbidities, ABG parameters, laboratory findings, hemodynamic status, PESI score, and thrombus localization on CTPA at the time of admission. ABG measurements were obtained at admission as part of routine clinical assessment. Patients were grouped as survivors or non-survivors based on hospital outcome. Prognostic assessment included pro-BNP levels, PESI score, systolic blood pressure (BP), and anatomical localization of the thrombus on CTPA. Continuous variables are shown as mean $\pm$ standard deviation SD, and categorical variables as numbers and percentages. Groups were compared using the t-test for continuous variables and the Chi-square test for categorical variables. Pearson correlation analysis was used to evaluate associations between continuous variables. We used logistic regression to identify factors that predict in-hospital mortality. We calculated odds ratios (ORs) and 95% confidence intervals (CIs). Data were analyzed using SPSS 26.0, and $p < 0.05$ was considered significant.

3. Results

1. Patient Demographic and Clinical Characteristics:

The study included 83 hospitalized patients with confirmed PE. The mean age was 69.3 ± 11.2 years. Of the patients, 56.6% (47) were female and 43.4% (36) were male. The most common comorbidities were cancer (27.7%), cardiovascular diseases (21.7%), and deep vein thrombosis (DVT) in 18% of the cases. In-hospital mortality was 42.2% ($n=35$). This elevated mortality rate compared to unselected PE populations likely reflects referral bias, hospitalization criteria, high comorbidity burden, and inclusion of severe central PE cases. The average hospital stay was 11 ± 7.2 days. Most patients (57.7%) reported symptoms for less than one week prior to hospitalization; of these, 65.7% ($n = 23$) died during their hospital stay.

2. Laboratory Parameters and ABG analysis upon admission

The ABG analysis at admission revealed the following (Table1):

Table 1. ABG parameters at admission

Parameter	Threshold	Prevalence (%)	N
Acidemia	pH < 7.35	6.0%	5
Alkalemia	pH > 7.45	42.2%	35
Hypocapnia	PCO ₂ < 35 mmHg	69.9%	58
Low bicarbonate	HCO ₃ ⁻ < 22 mmol/L	46.3%	38
Negative base excess	BE < -2 mmol/L	50.6%	42
Hypoxemia	PO ₂ < 60 mmHg	38.6%	32
Low oxygen saturation	SaO ₂ < 95%	81.7%	68

ABG analysis revealed frequent abnormalities: low oxygen saturation (SaO₂ < 95%) in 81.7% of cases, hypocapnia (PCO₂ < 35 mmHg) in 69.9%, and alkalemia (pH > 7.45) in 42.2%. Acidemia (pH < 7.35) was observed in only five patients; all of them died during hospitalization. However, due to the small number of cases, this result should be taken with caution. More than half of the patients (50.6%) had negative base excess (BE < -2 mmol/L), which was linked to a higher risk of death in logistic regression analysis.

Mortality and comparison between survivor and non-survivor groups.

Of the 83 patients, 42.2% (n = 35) died during hospitalization. There were no significant differences between survivors and non-survivors for the following variables (Table 2):

Table 2. Comparison of ABG parameters, laboratory values, systolic BP between survivors and non-survivors.

Parameter	Survivors (Mean± SD)	Non-survivors (Mean± SD)	p-value
pH	7.44±0.03	7.43±0.08	0.82
Base Excess (BE)	-2.1±4.6	-2.5±6.2	0.76
SaO ₂ (%)	90.8±9.3	86.7±14.9	0.18
PO ₂ (mmHg)	71.3±20.9	64.6±20.6	0.15
PCO ₂ (mmHg)	32±6.6	32.2±8.3	0.9
HCO ₃ ⁻ (mmol/L)	22±4.9	22.3±4.4	0.78
Systolic BP (mmHg)	126.5±18	119.6±18.7	0.97

Overall, the in-hospital mortality rate was 42.2%. Although some variables differed between groups, such as higher pro-BNP levels in non-survivors, these differences were not statistically significant. However, non-survivors had significantly higher PESI scores (mean 140 vs. 95, p < 0.001), and proved to be a strong independent predictor of mortality (Exp(B) = 31.4, 95% CI [6-145], p < 0.001). Although all patients with acidemia (pH < 7.35) died, this finding was not significant, likely due to the small sample size.

3. Correlation between clinical and laboratory variables

The following significant correlations were found (Table 3):

Table 3. Correlation between ABG parameters and laboratory variables, systolic BP, days of hospitalization.

Correlation	Coefficient (r)	p-value	Interpretation
pH and hospital stay (all patients)	-0.25	0.02	Weak negative correlation
pH and systolic BP (all patients)	0.30	0.01	Weak to moderate positive correlation
pH and hospital stay (exitus group)	0.40	0.01	Moderate positive correlation
PO ₂ and hospital stay (exitus group)	0.37	0.03	Moderate positive correlation
HCO ₃ ⁻ and hospital stay (exitus group)	0.34	0.04	Weak to moderate positive correlation

Statistically significant correlations were observed between ABG parameters and clinical variables,

such as pH and hospital stay ($r = -0.25$), pH and systolic blood pressure ($r = 0.30$) for all patients. Several statistically significant correlations were observed between ABG parameters and clinical variables. However, these associations should not be interpreted as evidence of causality. The observed correlations indicate relationships between variables but do not establish a direct effect on mortality or disease severity. In the subgroup of patients who died, pH, PO_2 , and HCO_3^- showed moderate positive correlations with length of hospital stay. These findings suggest an association with clinical course but do not demonstrate a prognostic effect on mortality.

PE was centrally located in 80% of cases. CTPA findings showed no significant differences in ABG parameters between central and peripheral PE.

4. Discussion

In this retrospective analysis of 83 hospitalized patients with PE, the relationship between ABG analysis parameters and clinical prognosis was evaluated. Among the main findings, although some ABG parameters did not reach statistical significance several clinically important trends were identified. Although arterial blood is used to assess acute PE severity (Oshima, 2006), our study found no statistically significant differences in ABG parameters (pH, PO_2 , PCO_2 , SO_2 , HCO_3^- , BE) as well as pro-BNP, PESI score, systolic BP, between survivors and non-survivors. PE impairs gas exchange by reducing blood flow in the lungs, causing ventilation-perfusion mismatch, dead space, hypoxemia, and, through mediator release, vasospasm and respiratory alkalosis (Nakos, 1998). Also patients with PE might have tachypnea (Vyas, 2024). Due to variability in arterial blood gases values, ABG analysis has limited usefulness in predicting PE (Weinberger, 2019). In another study HCO_3^- was identified as a significant predictor of mortality whereas other gas-analysis parameters were not significant predictors of mortality (Harmanjit, 2008). Arterial hypoxemia is a frequent but not universal finding in patients with acute embolism (Ouellette, 2024). No significant differences were found between the acidemia and non-acidemia groups of patients improved vs. exitus ($p > 0.05$), all patients with acidemia had exitus. In acute PE, hypercapnia reflects massive embolism accompanied by marked increases in both anatomic and physiological dead space (Goldhaber, 2003). Combined respiratory and metabolic acidosis in cases of massive PE (Stein, 1991; Stein, 1996). Negative BE as a prognostic factor for mortality. Metabolic disorders are negative prognostic indicators in patients with PE (Masotti, 2000). Pro- BNP is frequently useful for prognostication as it reflects indirect markers of right ventricular dilation and strain (Kucher, 2003; Belohl, 2013; Smithline, 2003) and is an independent risk factor associated with ABG parameters. The PESI score was higher in patients who died and predicted mortality. The 2014 ESC guidelines include the advanced risk stratification of PE patients using PESI classes I-III (Konstantinides, 2014). In all patients, pH had a weak negative correlation with length of hospital stay, which is statistically significant. Therefore, determining pH will help determine the risk of early or late mortality. In our study, pH showed a weak to moderate positive correlation with systolic blood pressure, which is statistically significant. "Massive" PE refers to its hemodynamic effect, not the size of the embolus. Hemodynamically unstable PE is associated with higher mortality due to obstructive shock, often linked to right ventricular failure. (Vyas, 2022; Sekhri, 2012). Therefore, determining pH will guide the massiveness or not of PE.

In patients who have died, a moderate and statistically significant positive relationship is observed between pH and hospital stay. The higher the pH, the longer the patients have stayed in the hospital, therefore the later they died. There is also a moderate and significant positive relationship between PO_2 , HCO_3^- and days of stay. Patients with better arterial oxygenation (higher PO_2), higher HCO_3^- have stayed longer in the hospital, therefore the later they died. Therefore, determining pH, PO_2 and HCO_3^- can determine the rapid or not risk of mortality. Hypoxemia is present in 98% of cases with PE, and persistent hypoxemia leads to the lactates accumulation and metabolic acidosis (Stein, 1996). CT scan findings may help assess risk in hemodynamically stable patients with PE. A pulmonary embolus is characterized as high-risk when both pulmonary arteries are involved (Ouellette, 2024). Pathological variations of ABG analysis significantly correlate with pathological reports of multi-slice computer tomography (MSCT) pulmonary angiography (Metafratzi, 2006).

In our study, no statistically significant differences in ABG parameters were observed according to the anatomical finding of the thrombus on CTPA ($p > 0.05$), likely due to multiple compensatory physiological mechanisms such as hyperventilation, redistribution of pulmonary blood flow, and variability in ventilation-perfusion mismatch—modulate gas exchange (Burrowes, 2011).

Patients with saddle emboli, although they constituted only a small part of the sample, showed severe acid-base disorders, with extreme values of BE (-14.0) and pH up to 7.10 , suggesting a pronounced metabolic compromise and a higher risk of severe clinical course. Thus, determination of pH can determine the probability of a central or peripheral localization of the thrombus. In patients who died, no significant association was found between ABG parameters and thrombus location on CTPA. However, clinical trends indicate that larger emboli (saddle, central) are associated with more pronounced acidosis and more severe hypoxemia. Larger studies are needed to confirm these findings and improve prognostic accuracy.

5. Limitations

This study has a number of limitations. Firstly, this study was done at a single center, which may limit how widely the results apply. Secondly, the small sample size and low number of events limit the study, especially for the complexity of the multivariate models. Thirdly, the potential referral bias in the study population should be considered when interpreting the findings, resulting in a higher mortality rate. Fourthly, oxygen therapy could have affected the values obtained from the ABG.

6. Conclusions

ABG abnormalities were common at presentation in patients with acute PE but, when analyzed individually, the majority of assessed parameters did not demonstrate an independent association with in-hospital mortality. Acidemia and negative base excess appeared to identify patients with poorer outcomes, although these findings require confirmation in larger studies. Correlation analyses further suggested that ABG parameters may help differentiate early from delayed adverse outcomes, with lower pH associated with shorter hospital stay and greater instability. Among all evaluated prognostic tools, PESI was the strongest and most consistent predictor of mortality. In contrast, thrombus localization on CTPA showed no significant prognostic value. Overall, ABG analysis should be considered a complementary assessment tool, with particular attention to acidemia and base excess, while PESI remains central to risk stratification in acute PE.

7. Acknowledgement

The authors declare that artificial intelligence tools were used during the preparation of this manuscript. Specifically, AI-assisted tools were used for language editing, grammar correction, and improvement of clarity. The intellectual content analysis, interpretation of results, and final approval of the manuscript remain the sole responsibility of the authors.

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