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ANALYSIS OF THE RELATIONSHIP BETWEEN BLOOD GAS PARAMETERS AND ELECTROCARDIOGRAPHY IN PATIENTS WITH DYSPNEA

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Abstract

Objectives: Dyspnea, a frequently encountered life-threatening symptom in Emergency Department admissions, prompts the utilization of various diagnostic tests such as blood gas analysis, complete blood count, and electrocardiography (ECG) to ascertain its cause and severity. This study aims to assess the association between blood gas parameters, complete blood count results, and electrocardiographic parameters. Additionally, the investigation focuses on identifying malignant arrhythmias and abnormalities in repolarization parameters (PR interval, QRS interval, QTc interval, Tp-e interval, and Tp-e/QTc ratio) in patients admitted to the Emergency Department with dyspnea.

Materials and Methods: The study includes individuals aged 18 and above who were admitted to the emergency department due to dyspnea. Upon admission, the patient's electrocardiographic parameters, blood gas results, complete blood count values, and other relevant laboratory findings were documented.

Results: Among the 385 patients studied, with a mean age of 64.6±17.7 years, 52.7% (n=199) were male. Analysis of the ECG results revealed a statistically significant prolongation of the QRS interval in acidotic and hypercapnic patients with dyspnea (p=0.041 and p=0.015, respectively). Similarly, the QTc interval was found to be significantly longer in acidotic and hypoxic patients presenting with dyspnea (p=0.011 and p=0.026, respectively).

Conclusion: Acidotic, hypoxic, and hypercapnic patients with dyspnea exhibited significantly prolonged QRS and QTc intervals. These findings suggest an elevated probability of ventricular arrhythmias in these patients.

Keywords: Dyspnea, electrocardiography, QRS interval, QTc interval.

Introduction

Dyspnea, characterized by the sensation of uncomfortable or difficult breathing, poses a significant threat to life and is a prevalent symptom among patients seeking care in Emergency Departments (EDs). Defined as the physician's interpretation of shortness of breath and the patient's response to this sensation, dyspnea can stem from various causes, ranging from less serious to severe, with a considerable portion linked to cardiac or respiratory disorders.[1,2] The incidence of Emergency Department admissions has been consistently rising, and dyspnea stands out as a major and frequent complaint leading to these admissions.[3] Hence, a prompt and accurate diagnosis of the underlying pathology causing dyspnea is imperative.[4]

To unravel the complexities associated with dyspnea, EDs employ numerous diagnostic tests aimed at identifying the cause and assessing its severity. Among these, blood gas analysis plays a crucial role in diagnosing and quantifying respiratory insufficiency, as well as evaluating acid-base disturbances in dyspneic patients upon admission. This diagnostic approach has been extensively applied in clinical studies examining various diseases associated with dyspnea.[5] Furthermore, blood count and other laboratory tests are essential for a comprehensive differential diagnosis at the time of admission.

Electrocardiography (ECG) emerges as a pivotal tool in the differential diagnosis of conditions such as acute coronary syndrome and pulmonary thromboembolism, which commonly manifest with dyspnea. Early utilization of ECG during admission facilitates the detection and assessment of cardiac arrhythmias. Markers such as PR interval, QRS and QTc intervals are indicative of risk factors that may lead to malignant ventricular arrhythmias, as established by previous studies.[6] Notably, the Tpeak-Tend (Tp-e) interval has been identified as a crucial parameter reflecting ventricular repolarization, while the Tp-e/QT ratio, independent of heart rate changes, provides more accurate results than QT dispersion.[7,8]

This study is designed to comprehensively evaluate the interplay between venous blood gas parameters, complete blood count results, and electrocardiographic parameters. The primary focus is on investigating malignant arrhythmias and alterations in transmural repolarization indicators, including PR interval, QRS interval, QTc interval, Tp-e interval, and Tp-e/QTc ratio, in patients admitted to the ED with dyspnea. The findings are expected to enhance our understanding of the intricate relationships between these parameters and contribute valuable insights to the management and diagnosis of dyspnea-related conditions.

Materials and Methods

Inclusion Criteria

This study was conducted within the Emergency Department of a tertiary hospital, focusing on patients aged 18 and above who were admitted due to dyspnea. Demographic parameters, including age, gender, comorbid diseases, electrocardiographic parameters, and laboratory results, were retrospectively obtained from hospital records in a six-month period. Electrocardiographic parameters, venous blood gas results, complete blood count values, and other laboratory findings were meticulously recorded at the time of admission. Patients meeting the inclusion criteria were subsequently enrolled in the study.

Exclusion Criteria

Participants under the age of 18, individuals for whom electrocardiograms (ECGs) were unattainable and subjects utilizing antiarrhythmic medications were deliberately omitted from the study cohort.

Definitions

All patients underwent a 12-lead ECG upon admission, with measurements conducted manually by a specialized cardiology professional. Evaluation of intervals included the PR interval, measured from the beginning of the P wave to the initiation of the QRS segment; the QRS interval, determined as the distance between the beginning of the Q wave and the end of the S wave; the QT interval, calculated from the beginning of the QRS complex to the downslope of the T wave. The corrected QT (QTc) interval was derived using Bazett's formula.[9] Additionally, the Tp-e interval, representing the distance from the peak of the T wave to its end, was assessed.[10]

This study received approval from the local ethics committee (ESH/GOEK 2022/13) and adhered to the principles outlined in the Helsinki Declaration.

Statistical Analysis

Data were presented as "mean ± standard deviation (SD)" for normally distributed variables, "median (interquartile range (IQR))" for non-normally distributed variables, and proportions for categorical variables. Normality distribution was assessed using the Shapiro–Wilk test and the Levene test was employed to test the homogeneity of group variances. Spearman correlation analysis was utilized to evaluate correlations between ECG results and other variables. A significance level of $P<0.05$ was considered for statistical significance. The data analysis was conducted using SPSS 20.0 (IBM SPSS Ver. 20.0; IBM Corp, Armonk, NY, USA).

Results

A total of 385 patients presenting with dyspnea symptoms were included in the study upon admission to the emergency department. The mean age of the study population was 64.6±17.7 years, with 52.7% (n=199) being male. Detailed demographic variables are presented in Table 1.

Table 1. Demographic parameters of the study population

Demographic Variables	
Age, years (mean±SD)	64.6±17.7
Gender, male (n, %)	199 (52.7%)
Hypertension (n, %)	154 (40.0%)
Diabetes Mellitus (n, %)	107 (27.8%)
Coronary Artery Disease (n, %)	77 (20.0%)
Chronic Obstructive Lung Disease (n, %)	54 (14.0%)

The examination of electrocardiographic parameters and venous blood gas results revealed noteworthy findings. Among the study population, 15.1% (n=58) had atrial fibrillation, while 83.9% (n=323) exhibited sinus rhythm. Additionally, 68.5% of the patients had heart rates within the normal range (n=264), while 31.5% demonstrated heart rates exceeding 100 bpm, indicative of tachycardia. Blood gas analysis indicated that 25.4% of the patients experienced acidosis (n=98), and 13.2% showed signs of alkalosis (n=51). Detailed electrocardiographic measurement results and blood gas findings are summarized in Table 1.

Correlation analyses unveiled significant relationships between various parameters. Positive correlations were observed between heart rate and lactate levels ($p<0.001$, $r=0.192$), while the QRS interval exhibited a negative correlation with pH ($p=0.041$, r:-0.105) and a positive correlation with pCO2 ($p=0.015$, $r=0.124$). QTc interval displayed a negative correlation with pH ($p=0.011$, $r=-0.130$) and SO2 ($p=0.026$, $r=-0.114$), along with a positive correlation with lactate levels ($p=0.039$, $r=0.105$). Detailed results of the correlation analysis between ECG parameters and blood gas results are presented in Table 2.

Table 2. ECG parameters and laboratory results of the study population.

ECG Parameters	
Rate, bpm, [median (IQR)]	87 (74-106)
PR interval, ms, [median (IQR)]	154 (137-174)
QRS interval, ms, [median (IQR)]	100 (90-115)
QT interval, ms, [median (IQR)]	374 (344.7-412.0)
QTc interval, ms, [median (IQR)]	454 (428-484)
Tp-e interval, ms, [median (IQR)]	35 (25-45)
QT dispersion, ms, [median (IQR)]	40 (30-60)
Tp-e/QT ratio, [median (IQR)]	0.10 (0.06-0.13)
Tp-e/QTc ratio, [median (IQR)]	0.08 (0.05-0.11)
Laboratory Parameters	
pH, [median (IQR)]	7.39 (7.34-7.42)
PCO2, mmHg, [median (IQR)]	43.6 (38.5-50.3)
PO2, mmHg, [median (IQR)]	32.0 (23.9-42.9)
SO2, [median (IQR)]	58.4 (28.5-77.5)
Lactate, mmol/L, [median (IQR)]	1.5 (1.1-2.1)
WBC, 10^3/µL, [median (IQR)]	9.4 (7.3-11.9)
HGB, g/dl, (mean ± SD)	12.8 ± 2.3
MCV, fL, (mean ± SD)	89.0 ±7.4
MCH, pg, [median (IQR)]	28.9 (27.1-30.4)
MCHC, g/dl, [median (IQR)]	32.0 (31.1-33.3)
RDW, %, [median (IQR)]	13.4 (12.3-14.9)
NEU, 10^3/µL, [median (IQR)]	5.85 (4.44-8.61)
Mono, 10^3/µL, (mean ± SD)	0.71 ± 0.30

Bpm: Beats per minute, ms: millisecond, pH: potential of hydrogen, pCO2: partial pressure of carbon dioxide, p02: partial pressure of oxygen, SO2: saturation of oxygen, mmHg: milimetres of mercury, mmol/L: milimoles per liter, L: liter, µL:microliter, dl: deciliter, WBC: white blood cell, g: gram, HGB: haemoglobin, MCV: mean corpuscular volume, fL:femtoliters, MCH: mean corpuscular haemoglobin, pg:picograms, MCHC: mean corpuscular haemoglobin concentration, RDW: red cell distrubition width, NEU: neutrophil, Mono: monocytes

Exploring the associations between ECG parameters and complete blood count results, several noteworthy correlations emerged. Heart rate exhibited positive correlations with white blood cell (WBC) count ($p<0.001$, $r=0.277$), RDW levels ($p<0.001$, $r=0.276$), and neutrophil counts ($p<0.001$, $r=0.300$), but demonstrated negative correlations with MCH levels ($p=0.032$, $r=-0.110$) and MCHC levels ($p=0.010$, $r=-0.132$). PR interval displayed negative correlations with WBC count ($p=0.003$, $r=-0.168$), platelet counts ($p=0.002$, $r=-0.171$), PTC values ($p=0.001$, $r=-0.180$), and neutrophil count ($p=0.021$, $r=-0.130$). Positive correlations were observed between the QRS interval and monocyte count ($p=0.022$, $r=0.118$), while negative correlations were noted with platelet levels ($p=0.008$, $r=-0.136$). QT interval demonstrated positive correlations with lymphocyte count ($p=0.034$, $r=0.109$), eosinophil count ($p=0.040$, $r=0.105$), and negative correlations with WBC count ($p<0.001$, $r=-0.214$), RDW ($p=0.022$, $r=-0.118$), neutrophil count ($p<0.001$, $r=-0.208$), and monocyte count ($p=0.012$, r=-

0.128). QTc interval exhibited positive correlations with WBC count (p=0.020, r=0.119), RDW (p<0.001, r=0.252), and neutrophil count (p=0.007, r=0.139) while demonstrating negative correlations with hemoglobin levels (p=0.006, r=-0.139) and MCHC levels (p=0.003, r=-0.150). Tp-e interval displayed a negative correlation with RDW (p=0.006, r=-0.152). QT dispersion showed positive correlations with PTC values (p=0.042, r=0.155), neutrophil levels (p=0.021, r=0.176), and negative correlations with MCHC values (p=0.008, r=-0.202). The Tp-e/QTc ratio exhibited a negative correlation with MCV values (p=0.021, r=-0.248).

Discussion

This study sheds light on the association between dyspnea and electrocardiographic parameters, venous blood gas results, and complete blood count values, offering valuable insights into the potential risk of cardiac arrhythmias in specific patient groups. The findings indicate that dyspneic patients with acidosis, hypoxia, and hypercapnia exhibit prolonged QRS and QTc intervals, suggesting an elevated risk for cardiac arrhythmias.

The dyspnea-related increase in respiratory effort triggers anaerobic respiration, leading to lactate accumulation.[11] Simultaneously, dyspnea patients may experience cardiac arrhythmias and heightened heart rates due to increased respiratory work.[12] The positive correlation observed in this study between heart rate and lactate levels aligns with existing literature.

The study delves into the significance of white blood cell (WBC) count and its subtypes as markers of stress and inflammation in dyspnea. Elevated WBC counts have been correlated with an increased risk of atrial fibrillation (AF) and cardiac arrhythmias.[13] Additionally, the study reveals that as hemoglobin levels drop, compensatory mechanisms are activated to counter tissue hypoxia.[14] The predominant factor crucial for addressing hypoxia is an elevation in cardiac output. Hemodynamic mechanisms achieve this by diminishing afterload, augmenting preload, and inducing positive inotropic and chronotropic effects. Moreover, in anemic patients, the heart rate escalates due to chemoreceptors activated by hypoxia.[15] In the present study, it was found that the heart rate rises concomitantly with an increase in WBC count and neutrophil count. Concurrently, the heart rate was found to escalate as the mean corpuscular hemoglobin (MCH) level and mean corpuscular hemoglobin concentration (MCHC) level decreased, aligning with previous research findings.

Prolongation of PR interval, associated with worse outcomes such as AF, stroke, and death, is highlighted.[16] The research has demonstrated that the extension of the QRS interval may lead to myocardial ischemia and ventricular arrhythmias, contributing to potentially fatal conditions.[17,18] In a study conducted by Terzano et al., it was observed that hypercapnia could elevate arterial blood pressure, stimulate increased cardiac output, and enhance the propensity for arrhythmias in patients with chronic obstructive pulmonary disease (COPD).[19] In this study, we observed a prolongation of the QRS interval in acidotic and hypercapnic patients exhibiting

dyspnea. Suzuki et al. reported in their study that the onset of AF correlated with elevated monocyte and WBC counts.[20] In our study, we identified a shortened PR interval with elevated WBC and neutrophil counts, while the QRS interval was prolonged with an increased monocyte count.

Prolongation of the QTc interval is recognized as a contributing factor to the occurrence of malignant ventricular arrhythmias and sudden cardiac death.[21] In a study conducted by Stewart et al., it was determined that QTc prolongation is prevalent in hypoxemic chronic obstructive pulmonary disease (COPD), posing a heightened risk of mortality.[22] Our study corroborates these findings, revealing an elevated QTc interval in patients characterized by acidosis, hypoxia, and heightened lactate levels. In the investigation undertaken by Fava et al., Red Cell Distribution Width (RDW) emerged as a valuable indicator for prognostic evaluation across a spectrum of cardiovascular conditions, including AF, stroke, and heart failure.[23] Likewise, Simsek et al. established a correlation between anemia and AF in their study.[24] Consistent with earlier research, our study identified a lengthening of the QTc interval associated with elevated RDW, WBC and neutrophil counts, as well as diminished hemoglobin and MCHC levels.

In our study, an assessment of the Tp-e interval and Tp-e/QTc ratio was undertaken. Existing literature demonstrates an association between the Tp-e interval, Tp-e/QTc ratio, ventricular repolarization abnormalities, and an elevated risk of cardiac arrhythmia.[6,25,26] This association has been substantiated in studies by Onur et al., revealing an increased Tp-e interval in patients with COPD.[27] Contrary to these findings, our study did not observe significant differences in Tp-e interval and Tp-e/QTc ratio among patients presenting with dyspnea. Furthermore, in their research, Rayes et al. highlighted the association between adverse outcomes in critically ill patients and individuals with cardiovascular disease and factors such as anemia, elevated RDW, or mean corpuscular volume (MCV).[28] In our investigation, we identified a prolonged Tp-e interval with low RDW values and a prolonged Tp-e/QTc ratio with low MCV values.

QT dispersion, indicating regional disparities in ventricular repolarization, is found to increase in dyspnea patients with high neutrophil levels and low MCHC values. This heightened heterogeneity in myocyte repolarization is identified as a potential risk factor for ventricular arrhythmias.[29] In this study, QT dispersion was found to increase at high neutrophil levels and at low MCHC values.

In summary, the study provides comprehensive insights into the intricate relationships between dyspnea, electrocardiographic parameters, and hematological markers, paving the way for further research and clinical considerations in managing dyspneic patients with potential cardiac risks.

In conclusion, in summary, our study identifies significant electrocardiographic parameter disturbances associated with ventricular arrhythmias and AF in dyspnea patients. While existing literature has explored various aspects of dyspnea, our research stands out as the first comprehensive study evaluating all

electrocardiographic parameters—PR interval, QRS interval, QTc interval, Tp-e interval, Tp-e/QTc ratio, and QT dispersion—in conjunction with blood gas and complete blood count results. The implications of these findings are substantial, potentially influencing treatment approaches for dyspnea patients.

Despite the absence of arrhythmias detected at the time of admission, our study underscores the importance of continuous monitoring for potential cardiac arrhythmias in dyspnea patients. Recommendations for further management may include 24-hour Holter monitoring or extended hospitalization with continuous ECG monitoring, particularly for patients exhibiting abnormal PR interval, QRS interval, Tp-e interval, and Tp-e/QTc ratio.

Limitations

A notable limitation of our study is the reliance on a single ECG taken at the time of admission. Given the dynamic nature of cardiac arrhythmias, an extended follow-up period for rhythm control would provide a more comprehensive understanding of the long-term implications in dyspnea patients. Additionally, the manual assessment of ECG by a single physician introduces a potential source of bias. To enhance the study's robustness, future research should involve multiple physicians in the ECG assessment process, ensuring a more rigorous and unbiased evaluation of electrocardiographic parameters in dyspnea patients.

Ethical Considerations: This study received approval from the local ethics committee (ESH/GOEK 2022/13) and adhered to the principles outlined in the Helsinki Declaration.

Conflict of Interest: The authors declare no conflict of interest.

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