STUDY OF SERUM ELECTROLYTE IMBALANCE AND ABG ABNORMALITIES IN PATIENTS WITH ACUTE EXACERBATION OF COPD

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ABSTRACT

Background: Acute Exacerbation of Chronic Obstructive Pulmonary Disease (AECOPD) is a frequent cause of hospitalization in patients with COPD. It is commonly associated with disturbances in arterial blood gas (ABG) parameters and serum electrolytes. Since these abnormalities may indicate the need for ventilatory support, early identification of these changes can help clinicians plan appropriate management. The current study aimed to determine the ABG abnormalities in patients with AECOPD.

Methods: This prospective study was conducted in 50 cases of AECOPD admitted to our hospital. The age of the patients was ≥ 40 years. Demographic and clinical details of the cases were recorded in a standard proforma. Patients were subjected to estimation of Serum sodium, potassium, and chloride levels, which were measured using an ion-selective electrode analyzer. The arterial blood gas analysis was performed using a calibrated blood gas analyzer. The duration of hospital stay was also recorded. The results were analyzed by using appropriate statistical analysis.

Results: The mean age of the patients was 64.5 ± 9.2 years. Male dominance was seen with male patients constituting 76% of cases. Electrolyte abnormalities were found in 78% of cases, and hyponatremia was the common electrolyte abnormality in 52%. ABG abnormalities were recorded in 92% cases. Respiratory acidosis (56%) and Type II respiratory failure (60%) of cases. Mean serum sodium, potassium, and chloride levels differed significantly across ABG categories. Patients with electrolyte abnormalities required ventilatory support 76.9% versus 45.5% without electrolyte abnormalities, and the p-values were significant.

Conclusion: This study found that serum electrolyte and ABG abnormalities are common in AECOPD. The abnormalities were closely associated with disease severity, requirement for ventilatory support, and duration of hospital stay. Therefore, assessment of serum electrolytes with arterial blood gas analysis can facilitate early identification of high-risk patients and improve prognosis by appropriate clinical management.

Keywords: Acute Exacerbation of COPD (AECOPD), Chronic Obstructive Pulmonary Disease (COPD), Arterial Blood Gas (ABG), Serum Electrolytes.

INTRODUCTION

Chronic Obstructive Pulmonary Disease (COPD) is a chronic lung disease characterized by chronic airway inflammation, persistent airflow restriction, and structural changes within the lungs.

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It continues to be one of the leading causes of morbidity and mortality across the world, resulting in a significant clinical and economic burden on healthcare systems. COPD is now one of the leading causes of death for respiratory diseases across the world, and acute exacerbations are an important cause of hospitalisation, healthcare costs, and mortality caused by COPD[1,2]. Acute exacerbation of COPD (AECOPD) is an acute deterioration in symptoms of COPD beyond the usual daily fluctuations in symptoms and signs that requires additional medical attention. It is often triggered by respiratory infections, pollutants, and other inflammatory insults and frequently leads to respiratory failure, necessitating hospitalization[2,3]. The pathophysiology of AECOPD includes airflow obstruction as well as abnormalities in arterial blood gases (ABG) caused by progressive ventilation-perfusion mismatch, increased airway resistance, respiratory muscle fatigue, and impaired alveolar

gas exchange. During exacerbations, hypoxemia is a frequent occurrence, and carbon dioxide retention can occur due to alveolar hypoventilation. In severe cases, it can lead to acute or acute-on-chronic hypercapnic respiratory failure (ARF) accompanied by respiratory acidosis. Arterial blood gases (ABGs) are thus useful in determining the extent of respiratory failure and are crucial in planning therapies such as oxygen therapy, non-invasive ventilation, and mechanical ventilation if required[3,4]. Acute exacerbations often cause electrolyte abnormalities, but they are not always the focus of attention as compared to respiratory parameters. Changes in serum sodium, potassium, chloride, calcium, and magnesium can occur because of systemic inflammation, hypoxia, respiratory acidosis, renal dysfunction, inadequate nutritional intake, dehydration, and the use of medicines like diuretics, corticosteroids, and β2-agonists. Hyponatremia is one of the major causes of prolonged hospitalization and increased risk of mortality. Likewise, hypokalemia and hypomagnesemia can increase the patient's susceptibility to cardiac arrhythmias, muscle weakness, and dysfunction of the respiratory muscles, which can make the recovery process more difficult. Renal impairment or severe acidosis can also cause hyperkalemia in patients, which should be recognized and treated promptly[5–8]. The relationship between acid-base disturbances and electrolyte imbalances is closely related. Carbon dioxide retention and respiratory acidosis affect electrolyte distribution, notably of potassium, both inside and outside the cell. A few renal compensatory mechanisms also contribute to the regulation of electrolyte balance during long-term respiratory failure. Therefore, the interpretation of electrolyte abnormalities should always be coupled with the accompanying ABG abnormalities to give a more accurate picture of physiological derangements. A combined evaluation of both parameters gives a more complete picture of the metabolic and respiratory status of the patient[4,7]. It is important to make an early diagnosis of ABG abnormalities and electrolyte imbalance, as these have clinical implications in patients presented for admission for AECOPD. Recognition of these abnormalities can be helpful to correct them in time, prevent complications, and improve treatment outcomes. Even with all the progress made in the management of COPD, information on the pattern of electrolyte disturbances in relation to ABG disturbances is lacking in many tertiary care centers, especially in the Indian population. In addition, some of these abnormalities may be affected by the severity of the disease, comorbid conditions, and medical treatment given to patients[5,8]. With this background, the present study was designed to assess the spectrum of serum electrolyte disturbance and arterial blood gas abnormalities seen in patients hospitalized with acute exacerbation of COPD.

MATERIALS AND METHODS

This prospective observational study was conducted in the Department of Pulmonary Medicine at a tertiary care teaching hospital. Institutional ethical approval was obtained for the study. Written consent was obtained from all the participants of the study after explaining the nature of the study and possible outcomes in the vernacular language. Care was taken to maintain the anonymity of the patients as per protocol.

Inclusion Criteria

1. Patients aged ≥40 years.
2. Previously diagnosed cases of COPD based on clinical features and spirometry (where available) or documented medical records.
3. Patients admitted with acute exacerbation of COPD, defined as an acute worsening of respiratory symptoms requiring additional medical treatment and hospitalization.
4. Patients who provided written voluntary informed consent.

Exclusion Criteria

1. Patients with bronchial asthma or asthma-COPD overlap syndrome.
2. Patients with chronic kidney disease, nephrotic syndrome, or acute kidney injury.
3. Patients with chronic liver disease.
4. Patients with congestive heart failure presenting with pulmonary edema.
5. Patients with endocrine disorders affecting electrolyte balance (e.g., adrenal insufficiency, uncontrolled thyroid disorders).
6. Patients receiving dialysis.
7. Patients with active malignancy.

Sample Size Calculation: The sample size was calculated using the formula for estimating a single population proportion:

$n = Z^2 \times p \times (1 - p) / d^2$

where $Z = 1.96$ for a 95% confidence interval, $p = 0.78$ (expected prevalence of electrolyte abnormalities among patients with acute exacerbation of COPD based on previous studies), and $d = 0.12$ (absolute precision). The calculated minimum sample size was approximately 46 patients. To compensate for possible incomplete data, 50 patients were included in the study.

Based on the inclusion and exclusion criteria and sample size calculation of the study, a total of 50 consecutive patients were included in the study for analysis. The selected cases were subjected to a detailed clinical history, including age, sex, smoking status, occupational exposure, duration of COPD, previous exacerbations, associated comorbidities, current medications, and presenting symptoms such as dyspnea, cough, sputum production, wheezing, and fever. A complete physical examination was

performed, including assessment of vital parameters, respiratory rate, oxygen saturation, blood pressure, pulse rate, body temperature, and systemic examination. The severity of dyspnea was documented using the Modified Medical Research Council (mMRC) dyspnea scale whenever feasible. Laboratory Investigations were done within the first 24 hours after admission. The parameters included complete blood count, random blood glucose, blood urea, serum creatinine, liver function tests, electrocardiogram (ECG), and chest radiograph. Venous blood samples were collected under aseptic precautions before initiation of intravenous fluid therapy whenever possible. Serum electrolytes, including Sodium (Na^+), Potassium (K^+), and Chloride (Cl^-), were estimated using an automated biochemistry electrolyte analyzer based on the ion-selective electrode (ISE) method.

Arterial Blood Gas Analysis: Arterial blood samples were obtained from the radial artery under aseptic precautions before initiation of non-invasive ventilation whenever feasible and analyzed immediately using a calibrated blood gas analyzer. The ABG parameters recorded were pH, Partial pressure of oxygen (PaO_2), Partial pressure of carbon dioxide ($PaCO_2$), Bicarbonate (HCO_3^-), and Oxygen saturation (SaO_2). Respiratory failure was classified according to standard definitions: Type I respiratory failure: PaO_2 <60 mmHg with normal or low $PaCO_2$. Type II respiratory failure: PaO_2 <60 mmHg with $PaCO_2$ >45 mmHg.

Outcome Measures: The primary outcome was to determine the prevalence and pattern of serum electrolyte abnormalities and ABG abnormalities among patients with AECOPD.

Secondary outcomes included in the study analysis were the distribution of different electrolyte abnormalities, the pattern of acid-base disturbances, the association between electrolyte abnormalities and ABG findings, the requirement of non-invasive or invasive ventilatory support, and the duration of hospital stay.

Statistical Analysis: The data were entered into a Microsoft Excel spreadsheet and analyzed using Statistical Package for the Social Sciences (SPSS) software version 29.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation or median with interquartile range, depending on data distribution. Categorical variables were presented as frequencies and percentages. The student's independent t-test for normally distributed data. Kruskal-Wallis test was conducted two ABG groups. Correlation between serum electrolyte levels and ABG parameters was assessed using Pearson's (r) correlation coefficient, depending on data distribution. A p-value <0.05 was considered statistically significant.

RESULTS

Baseline demographic and clinical characteristics of the study patients are depicted in Table 1. Analysis of the table showed the following characteristics: the mean age was 64.5 ± 9.2 years. Males were frequent, with 76% of the total cases. Smoking status showed that 44% were current smokers, 36% were former smokers, and 20% had never smoked. The mean duration of COPD was 8.4 ± 3.7 years. Based on the modified Medical Research Council (mMRC) dyspnea scale, nearly half of the patients, 48%, had Grade 4 dyspnea, followed by 36% with Grade 3 and 16% with Grade 2 dyspnea. Ventilatory support was required in more than half of the patients, with 48% managed using non-invasive ventilation (NIV) and 10% requiring invasive mechanical ventilation, while 42% did not require ventilatory support. The mean duration of hospital stay was 7.2 ± 3.5 days.

Table 1: Baseline Demographic and Clinical Characteristics of the Study Population

Characteristic	***Category / Measure***	***Value***
Age (years)	Mean ± SD	64.5 ± 9.2
Sex	Male, n (%)	38 (76%)
	Female, n (%)	12 (24%)
Smoking Status	Current Smoker, n (%)	22 (44%)
	Former Smoker, n (%)	18 (36%)
	Non-Smoker, n (%)	10 (20%)
Duration of COPD (years)	Mean ± SD	8.4 ± 3.7
mMRC Dyspnea Scale	Grade 2, n (%)	8 (16%)
	Grade 3, n (%)	18 (36%)
	Grade 4, n (%)	24 (48%)
Requirement of Ventilatory Support	None, n (%)	21 (42%)
	Non-invasive Ventilation (NIV), n (%)	24 (48%)
	Invasive Mechanical Ventilation, n (%)	5 (10%)
Duration of Hospital Stay (days)	Mean ± SD	7.2 ± 3.5

Prevalence and pattern of serum electrolyte abnormalities are depicted in Table 2. The analysis of the table showed that 39 patients (78%) had at least one electrolyte abnormality. Serum sodium abnormalities were the most frequent, occurring in 60% of patients. Hyponatremia was observed in 52%, whereas hypernatremia was present in 8%. Potassium abnormalities were detected in 36% of patients, with hypokalemia accounting for 30% and hyperkalemia for 6% (n=3). Chloride abnormalities were present in 44%, including hypochloremia in 34% and hyperchloremia in 10% of patients. Hyponatremia emerged as the most frequent electrolyte disturbance, followed by hypochloremia and hypokalemia.

Table 2: Prevalence and Pattern of Serum Electrolyte Abnormalities

Electrolyte Parameter	Normal Range	Finding	n (%)
Serum Sodium (Na^+)	135 — 145 mmol/L	Abnormal, Total	30 (60%)
		Hyponatremia (<135 mmol/L)	26 (52%)
		Hypernatremia (>145 mmol/L)	4 (8%)
Serum Potassium (K^+)	3.5 — 5.0 mmol/L	Abnormal, Total	18 (36%)
		Hypokalemia (<3.5 mmol/L)	15 (30%)
		Hyperkalemia (>5.0 mmol/L)	3 (6%)
Serum Chloride (Cl^-)	98 -107 mmol/L	Abnormal, Total	22 (44%)
		Hypochloremia (<98 mmol/L)	17 (34%)
		Hyperchloremia (>107 mmol/L)	5 (10%)
Overall Electrolyte Imbalance		Patients with at least one abnormality	39 (78%)

The pattern of arterial blood gas abnormalities is recorded in Table 3. Arterial blood gas analysis demonstrated abnormalities in 92% (n=46) of the patients, while only 8% had normal ABG findings. Respiratory acidosis was the predominant acid-base disorder, affecting 56% of patients. Mixed acid-base disorders were identified in 18%, followed by respiratory alkalosis in 8%, metabolic acidosis in 6%, and metabolic alkalosis in 4%. Respiratory failure was present in 84% of the study population. Among these patients, Type II respiratory failure was the most common, occurring in 60%, whereas 24% had Type I respiratory failure. Only 16% of patients had no evidence of respiratory failure.

Table 3: Pattern of Arterial Blood Gas (ABG) Abnormalities

ABG Parameter	Category	N (%)
Acid-Base Disorder	Normal ABG	4 (8%)
	Abnormal, Total	46 (92%)
	Respiratory Acidosis	28 (56%)
	Respiratory Alkalosis	4 (8%)
	Metabolic Acidosis	3 (6%)
	Metabolic Alkalosis	2 (4%)
	Mixed Acid-Base Disorder	9 (18%)
Type of Respiratory Failure	No Respiratory Failure	8 (16%)
(n=42 patients With PaO_2<60 mmHg)	Type I Respiratory Failure (PaO_2 <60 mmHg, normal/low $PaCO_2$)	12 (24%)
	Type II Respiratory Failure (PaO_2 <60 mmHg, $POCO_2$ >45 mmHg)	30 (60%)

Distribution of serum electrolyte levels according to ABG findings is given in Table 5. The mean serum electrolyte levels differed significantly across various ABG categories. Patients with normal ABG findings had mean serum sodium, potassium, and chloride levels of 140 ± 2.1 mmol/L, 4.1 ± 0.4

mmol/L, and 103.5 ± 1.9 mmol/L, respectively. Patients with respiratory acidosis demonstrated lower mean sodium (132.5 ± 4.8 mmol/L) and chloride (96.2 ± 4.5 mmol/L) levels, with a relatively higher potassium level (4.5 ± 0.8 mmol/L). The lowest mean serum sodium concentration (130.5 ± 5.1 mmol/L) was observed among patients with mixed acid-base disorders. Hyperkalemia was most evident in patients with metabolic acidosis (5.2 ± 0.6 mmol/L), while the lowest chloride level was recorded in patients with metabolic alkalosis (88.5 ± 1.5 mmol/L). Differences in serum sodium ($p<0.001$), potassium ($p=0.002$), and chloride ($p=0.001$) across ABG categories were statistically significant.

Table 4: Distribution of Mean Serum Electrolyte Levels According to Findings

ABG Category	n	Serum Sodium (Na^+) Mean ± SD (mmol/L)	Serum Potassium (K^+) Mean ± SD (mmol/L)	Serum Chloride (Cl^-) Mean ± SD (mmol/L)
Normal ABG	4	140 ± 2.1	4.1 ± 0.4	103.5 ± 1.9
Respiratory Acidosis	28	132.5 ± 4.8	4.5 ± 0.8	96.2 ± 4.5
Respiratory Alkalosis	4	138.2 ± 3	3.2 ± 0.3	105 ± 2.0
Metabolic Acidosis	3	134 ±2.5	5.2 ±0.6	95.5 ± 3.2
Metabolic Alkalosis	2	136.5 ± 1.5	3.0 ± 0.2	88.5 ± 1.5
Mixed Acid-Base Disorder	9	130.5 ± 5.1	4.8 ± 0.9	94.8 ±4.1
p-value		<0.001	0.002	0.001

The association between electrolyte abnormalities and clinical outcomes is depicted in Table 5. Patients with electrolyte imbalance experienced poorer clinical outcomes compared with those without electrolyte abnormalities. Among patients with electrolyte imbalance, 76.9% (30/39) required either non-invasive or invasive ventilatory support compared with 45.5% (5/11) of patients with normal electrolyte levels, and this difference was statistically significant ($p=0.04$). Similarly, the mean duration of hospital stay was significantly longer among patients with electrolyte imbalance (8.1 ± 3.4 days) than among those without electrolyte abnormalities (5.0 ± 2.1 days) ($p=0.02$).

Table 5: Association between Electrolyte Abnormalities and Clinical Outcomes

Outcome Variable	Patients With Electrolyte Imbalance (n =39)	Patients With No Electrolyte Imbalance (n=11)	p-value
Requirement of NIV/Invasive Ventilation, n (%)	30 (76.9%)	5 (45.5%)	0.04
Duration of Hospital Stay (days) Mean ± SD	8.1 ± 3.4	5.0 ± 2.1	0.02

Correlation between serum electrolyte levels and ABG parameters is given in Table 6. Serum electrolyte concentrations demonstrated significant correlations with several ABG parameters. Serum sodium showed a moderate positive correlation with arterial pH ($r=0.32$, $p=0.02$) and a significant negative correlation with $PaCO_2$ ($r=-0.55$, $p<0.001$), whereas its correlation with bicarbonate was not statistically significant ($r=0.18$, $p=0.21$). Serum potassium exhibited a significant negative correlation with pH ($r=-0.45$, $p=0.001$), $PaCO_2$ ($r=-0.38$, $p=0.006$), and bicarbonate ($r=-0.51$, $p<0.001$). Serum chloride also showed a negative correlation with pH ($r=-0.28$, $p=0.05$) and a moderate negative correlation with $PaCO_2$ ($r=-0.50$, $p<0.001$), while no significant association was observed with bicarbonate levels ($r=-0.15$, $p=0.30$). These findings indicate a significant relationship between electrolyte disturbances and the severity of acid-base abnormalities in patients with acute exacerbation of COPD.

Table 6: Correlation between Serum Electrolyte Levels and ABG Parameters

ABG Parameter	Serum Sodium (Na+)	Serum Potassium (K+)	Serum Chloride (Cl-)
pH	r = 0.32 p = 0 02	r = -0.45 p = 0.001	r = -0.28 p = 0.05
$PaCO_2$ (mmHg)	r = -0.55 p = <0.001	r = -0.38 p = 0.006	r = -0.50 p = <0.001
HCO_3^- (mmoI/L)	r = 0.18 p = 0.21	r = -0.51 p = <0.001	r = -0.15 p = 0.30

DISCUSSION

COPD is manifested by disturbances in electrolyte balance and arterial blood gas (ABG) parameters. Assessment of both is important to determine the severity of the disease and clinical outcomes. The present study showed that electrolyte disorder was seen in 78% of the patients and ABG disorder in 92% of the patients, indicating that acute exacerbations are systemic in nature. This shows that evaluation of electrolyte status must be considered as an integral part of the assessment for patients admitted to the hospital with AECOPD, not as a separate analysis[2,3]. The mean age was 64.5 years, with a significant male predominance (76%). The findings are consistent with previous Indian and international studies, in which elderly males are more likely to have COPD due to higher cumulative exposure to tobacco smoke and occupational pollutants[2,9]. Cigarette smoking continued to be an important risk factor for COPD exacerbation recurrence and progression. Approximately 80% of the patients of our study were current or former smokers in the present study[2,10]. In addition, nearly half of the patients had an mMRC grade 4 dyspnea, reflecting advanced disease with significant functional impairment. In the present study, electrolyte abnormalities were very common, with hyponatremia being the most common, followed by hypochloremia and hypokalemia. Acute respiratory infections are known to be associated with sodium imbalance, and 52% of patients had hyponatremia, as reported previously[5,8]. There are various possible mechanisms for this observation, such as syndrome of inappropriate antidiuretic hormone secretion, systemic inflammation, hypoxia-induced hormone activation, diuretic therapy, and decreased oral intake[11]. In patients with respiratory diseases, hyponatremia has also been shown to be an adverse predictor of mortality and extended hospital stay[8,11]. Hypokalemia occurred in 30% of patients, and hyperkalemia was relatively uncommon. Potassium abnormalities during COPD exacerbations are multifactorial and may result from β2-agonist therapy, corticosteroid administration, respiratory acidosis, renal dysfunction, or poor nutritional status[7,12]. Potassium is an important electrolyte for skeletal muscle and respiratory muscle function, and its disturbance can exacerbate weakness of respiratory muscles and increase the risk of ventilatory failure. Likewise, hypochloremia, which was observed in one-third of the patients, may be due to chronic carbon dioxide retention with renal compensation, diuretic therapy, or volume depletion. There is recent evidence that a low chloride level can be a predictive factor for poorer clinical outcomes in COPD patients [13].

In the present study, the abnormal ABG was found in 92% of the patients; the most common acid-base disorder was respiratory acidosis. This is not surprising as acute exacerbations frequently lead to exacerbation of ventilation-perfusion mismatch, alveolar hypoventilation, and carbon dioxide retention[3,4]. Type II respiratory failure was more prevalent in patients (60%) than was Type I respiratory failure. This has been described in hospitalized (severe AECOPD) patients with hypercapnic respiratory failure, often requiring non-invasive ventilatory support[2,14]. In 18% of the patients, a mixed acid-base disturbance was found, which represents the simultaneous occurrence of respiratory and metabolic disorders, which are frequently seen in patients in critical condition. One of the most important findings of this study was that electrolyte abnormalities were highly correlated with ABG findings. The patients who had respiratory acidosis and mixed acid-base disorders had a significantly lower level of sodium and chloride in their blood, while the patients with metabolic acidosis had a higher level of potassium. The physiological connections of these are well known; respiratory acidosis is known to influence transcellular electrolyte shifts and stimulate renal compensatory mechanisms, which regulate sodium, potassium, and chloride homeostasis[4,7]. The strong associations found between acid-base status and electrolyte status or pH and $PaCO_2$ also reinforce the link between acid-base and electrolyte control. Patients with electrolyte imbalance had significantly higher ventilatory support requirements and had a longer hospital stay when compared with those without electrolyte abnormalities. These results have clinical significance as they show that electrolyte disorders are not only laboratory abnormalities but may be associated with higher disease severity. In contrast, Singanayagam et al.[6] have been able to show, in the context of hospitalised COPD patients, that biochemical abnormalities were linked to worse outcomes. Similarly, combined electrolyte and acid-base disturbances were related to worsening clinical severity on acute exacerbations, as reported by

Terzano et al.[5] in their study. There are some limitations of the present study. It was done in one tertiary care centre and in a small sample population of 50 patients, so the results may not be generalizable. No serial electrolytes or ABGs were done during hospitalization, thus allowing no evaluation of dynamic changes with therapy. Furthermore, the multiple medications and concurrent conditions (comorbidities) that may affect electrolyte abnormalities were not analyzed individually. However, the study offers valuable insights into the widespread occurrence of electrolyte disturbances in AECOPD and the association between these disturbances and acid-base disturbances and clinical outcomes. In general, the results showed that the serum electrolyte disorders and ABG derangements are closely associated in patients with acute exacerbation of COPD. The frequent monitoring of both parameters at the time of admission could help to identify patients at increased risk of respiratory failure, long stay, and ventilatory support, which would allow timely and adequate clinical management.

CONCLUSION

The present study demonstrates that serum electrolyte imbalance and arterial blood gas abnormalities are highly prevalent among patients admitted with acute exacerbation of COPD. Hyponatremia, hypochloremia, and hypokalemia were the most common electrolyte disturbances, while respiratory acidosis and Type II respiratory failure were the predominant ABG abnormalities. Significant associations were observed between electrolyte derangements, acid-base abnormalities, increased requirement for ventilatory support, and prolonged hospital stay. These findings underscore the importance of routine assessment of serum electrolytes and ABG parameters at the time of admission, enabling early identification of high-risk patients, timely correction of abnormalities, and optimization of clinical management to improve patient outcomes.

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