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Explore The Common Types Of Acid-Base Disturbances Among Critically Ill Patients In Intensive Care Unit

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Abstract

Background: Acid-base disturbances are common in critically ill patients and pose a great burden in the management of the underlying condition. **Aim:** To explore the common types of acid-base disturbances among the critically ill patients in ICU. **Design*:*** A descriptive study design was utilized. **Setting:** This study was carried out in the Trauma and general Intensive Care Units at Assiut university hospital. **Sample:** Eighty adult male and female patients admitted to trauma and general ICUs. **Tools:** Three tools were used in this study, patient assessment tool, APACHE II tool, and Acid-base parameters assessment tool. **Result:** Eighty patients suffered from acid-base disorders with mean age (41.88 ±13.39) years. The mean pH on admission was (7.34 ±0.13), the mean length of ICU stay was (10.90 ±7.86). Respiratory alkalosis was the most frequent of simple acid-base disturbance (73.8%) followed by metabolic alkalosis (33.8%), respiratory acidosis (32.5%). Mixed acid-base disorders were relatively less frequent, the common combination was metabolic acidosis with respiratory acidosis (15.0%). **Conclusion:** Acid-base disturbance are common among critically ill patients presenting at the ICU. Respiratory alkalosis was the most frequent simple acid-base disturbance was observed among such group of patients. **Recommendation**: Acid-base disturbance should be monitored closely, diagnosed early, and managed correctly during hospitalization.

Keywords: Acid-base Disturbances, Critically Ill Patients &ICU.

Introduction

Acid-base disturbances are commonly encountered in clinical practice, especially in critical care units. Identification of the specific acid-base imbalance is important in ascertaining the underlying cause of the disorder and determining appropriate treatment. **(Johnson & Crumlett, 2018)**.

The incidence of acid-base disturbances may be varied depending on the different underlying diseases and comorbidities. The presence of these disorders does not only signal severe underlying pathophysiology but also is a significant marker of adverse outcomes. These disorders may occur in the progression of diseases such as diabetes mellitus, acute or chronic renal failure, acute or chronic respiratory failure, shock, and severe cardiovascular events, while some life-threatening imbalances may be iatrogenically induced **(Hu et al., 2017).**

The two principal disturbances of the acid-base balance are acidosis and alkalosis. Each is further divided into respiratory and metabolic types. Acidosis and alkalosis result in acidemia and alkalemia, respectively. Further classification takes on account respiratory and metabolic components. If the primary cause is a change in the partial pressure of arterial carbon dioxide (PCO2), acidosis or alkalosis is called respiratory, and if it is in the bicarbonate concentration, acidosis or alkalosis is called metabolic. **(Baynes & Dominiczak, 2019).**

Acid-base disorders are also classified according to the number of conditions causing the disorder. When only one primary acid-base abnormality and its compensatory mechanisms occur, the disorder is classified as a simple acid-base disorder. When a combination of simple acid-base disturbances occurs, the patient has a mixed acid-base disorder. Because secondary physiologic regulatory mechanisms often compensate for the alteration in pH caused by primary disturbances. **(Juul & Gleason, 2018).**

Critically ill patients commonly experienced a complex acid-base disorder. With one descriptive Cross-sectional Study showing that Simple and mixed acid-base disorders were observed in (46.24%) and (53.76%) patients. Amongst the patients with simple acid-base disorders, metabolic acidosis was identified in (14.3%), metabolic alkalosis in (6.1%), respiratory acidosis in (7.1%) and respiratory alkalosis in (18.7%). In the mixed acid-base disorders, it was noted that the maximum were suffering from metabolic acidosis and respiratory alkalosis (28.4%). The other mixed acid-base disorders were metabolic alkalosis and respiratory acidosis (15.6%), metabolic acidosis and respiratory acidosis (6.1%) and metabolic alkalosis and respiratory alkalosis (3.6%) **(Shreewastav et al., 2019).**

For identification of the primary disturbance, the analysis of blood gas values must be considering the patient's history and physical findings, and with an understanding of expected compensatory responses. Further laboratory evaluation is indicated if the problem is not immediately obvious or if the response to therapy is not as expected. **(Roberts et al., 2019).**

The nursing assessment is directed toward the following: Identifying patients at high risk for fluid, electrolyte, and acid-base imbalances. Determining that a specific imbalance is present and identifying the nature of the imbalance along with its severity, etiology, and defining characteristics or assessment findings. Determining the plan of care, including the appropriate nursing diagnoses or collaborative problems, followed by the identification of specific outcomes, associated interventions, and the evaluation of the effectiveness of the plan of care **(Peate & Wild, 2017)**.

Nursing interventions to promote acid-base balance support prescribed medical therapies and are aimed at reversing the acid-base imbalance that exists. Such imbalances can be life-threatening and require rapid correction. The nurse must maintain a functional IV line and frequently check the doctor's orders for new medications or fluids. Prescribed drugs, such as insulin or sodium bicarbonate, and fluid and electrolyte replacement should be given promptly. The nurse also monitors patients closely for changes in acid-base balance. **(Crisp et al., 2016).**

Significance of the study

Any patient is at risk for an acid-base imbalance, but it occurs most commonly as a complication of many acute and chronic health problems. Nurses play an important role in the early detection of high-risk clients with an acid-base imbalance in critical care units. Assessment of the acid-base status of critically ill patients is an integral component of the diagnostic workup of these cases as various acid-base disorders are present in such clinical scenarios. However, the pattern of acid-base disorders among critically ill patients being managed in acute care facilities is poorly reported. This study has been undertaken to describe the trend of acid-base disturbances during hospitalization among critically ill patients across different categories of intensive care units (ICUs).

Aims of the study

To explore the common types of acid-base disturbances in critically ill patients admitted in ICUs.

Research question

The study was directed to answer the following research question.

What are the common types of acid-base imbalance among critically ill patients in intensive care units?

Patients and Methods

Research design

A descriptive study design was used to fulfill the aim of this study**.**

Setting:

This study was carried out in the Trauma Intensive Care Unit (6 beds) and general Intensive Care Unit (12 beds)

Sample: purposive sample of adult male and female critically ill patients admitted consecutively to the above-mentioned settings of ICUs, between October 2018, and June 2019.

The sample size

The sample size was calculated using the EPI info 2000 statistical package. The calculation was done using the expected frequencies of acid-base disorders from previous studies using 95% confidence interval, 80% power of the study, 95.0% prevalence of the acid-base disorders, and worst acceptable result 5%. The sample size calculated according to the above criteria was 73 patients. However, 80 patients were attempted in this research work to avoid the non-response rate.

Inclusion criteria

1. Patients aged between 18 and 60 years old
2. Patients newly admitted to the ICU during the study period not exceeding 24 hours were included in the study.

Exclusion criteria

3. Patients without arterial blood gases and laboratory variables needed for the acid-base evaluation proposed were excluded.
4. Patients who transferred out of critical care area within 24 hours of arrival.

Tools of the study

Data pertinent to the study were collected, utilizing the following tools

Tool one: Patient Assessment Tool

This tool was developed by the researcher after reviewing the relevant literature to assess the patient's demographic data and health-relevant data it comprised of the following parts**.**

Part I- personal and Clinical data characteristics included gender, age, causes of admission to ICU, type of admission, place prior to admission, unit of admission, presence of comorbidities, mechanical ventilation on admission, renal failure on admission, vasopressors on admission**,** date of admission, date of discharge, length of stay, Glasgow Coma Scale (GCS) score on admission and discharge criteria.

Tool two: APACHE II score (Acute physiology and chronic health evaluation). The APACHE II is still commonly used as an index of illness severity among critically ill patients admitted to ICU and has been validated in many research and clinical audit purposes. **(Nath, 2017)** APACHE II is the severity of

disease classification system. It uses a point score based upon values of 12 routine physiologic measurements (taken during the first 24 hrs. after admission), age, and previous health status to provide a general measure of severity of the disease. An integer score from 0 to 71 is then computed based on these measurements; higher
scores imply a more severe disease and a higher risk of death **(Rapsang & Shyam, 2014)**.

A Scoring system of APACHE II (Acute physiology and chronic health evaluation) was adopted from **(Knaus et al., 1985)** The values were scored in accordance with the APACHE II chart scoring for abnormally
high or low range. The zero scores represent a normal value.

APACHE II Scoring system

(A) physiologic variable			
1-Temperature		**2- Arterial pH**	
>40 (4 points)	34-35.9 (1 point)	> 7.7 (4 point)	7.25-7.32 (2 point)
39-40.9 (3 points)	32-33.9 (2 points)	7.6-7.69 (3 point)	7.15-7.24 (3 point)
38.5-38.9 (1 point)	30-31.9 (3 points)	7.5-7.59 (1 point)	< 7.15 (4 point)
36-38.4 (0 point)	< 29.9 (4 points)	7.33-7.49 (0 point)	
3- MAP (mmHg)		**4- WBC (total/mm3)**	
> 160 (4 points)	70-109 (0 point)	> 40 (4 points)	3-14.9 (0 point)
130-159 (3 points)	50-69 (2 points)	20-39.9 (2 points)	1-2.9 (2 point)
110-129 (2 points)	< 49 (4 points)	15-19.9 (1 point)	< 1 (4 point)
5- Heart Rate		**6- Serum Na (mmol/L)**	
> 180 (4 points)	55-69 (2 points)	> 180 (4 points)	130-149 (0 point)
140-179 (3 points)	40-54 (3 points)	160-179 (3 points)	120-129 (2 point)
110-139 (2 points)	< 39 (4 points)	155-159 (2 points)	111-119 (3 point)
70-109 (0 points)		150-154 (1 point)	< 110 (4 point)
7- Respiratory Rate		**8- Serum K (mmol/L)**	
> 50 (4 points)	10-11 (1 point)	> 7 (4 points)	3-3.4 (1 point)
35-49 (3 points)	6-9 (2 point)	6-6.9 (3 points)	2.5-2.9 (2 point)
25-34 (1 point)	< 5 (4 point)	5.5-5.9 (1 point)	< 2.5 (4 points)
12-24 (0 points)		3.5-5.4 (0 point)	
9- Oxygenation:		**10- Hematocrit (%)**	
PO2 > 70 (0 point)	PO2 55-60 (3 point)	> 60 (4 points)	30-45.9 (0 point)
PO2 61-70 (1 *point*)	PO2 < 55 (4 point)	50-59.9 (2 points)	20-29.9 (2 point)
11- Serum Creatinine (µmol/L)		46-49.9 (1 point)	< 20 (4 point)
> 305 (4 points)	53-129 (0 points)		
170-304 (3 points)	<53 (2 points)		
130-169 (2 points)			
12- Glasgow Coma Score (GCS) Score = 15 minus actual GCS			
(B) Age point (< 44 = 0), (45-54 =2), (55-64 = 3), (65-74 = 5), (> 75 = 6)			
(C) Chronic Health Points - If the patient has a history of severe organ system insufficiency or is immunocompromised assign points as follows **a) Non-operative or emergency postoperative patients = 5 points** **b) Elective postoperative patients = 2 points**			
APACHE II SCORE - Sum of A (APS points) + B (Age points) + C (Chronic Health Points)			

Acute Physiology Score (APS): a sum of the 12 individual variable points =

Tool three: Acid-base Parameters Assessment Tool

This tool was developed by the researcher after reviewing the relevant literature to meet the need for the acid-base evaluation proposed it consists of the two parts.

Part I: Arterial Blood Gases Parameters Assessment sheet:

Acid-base parameters were calculated on arterial blood gases result. Analysis of the ABGs included pH values, the partial pressure of arterial carbon dioxide (PaCO2), the partial pressure of the arterial oxygen (PaO2), bicarbonate (HCO3), base excess (BE_{Ecf}), Oxygen Saturation (SaO2) and lactate.

Part II: Laboratory Investigations Assessment sheet;

Laboratory variables needed for the acid-base evaluation proposed like Serum electrolytes including sodium (Na), potassium (K), magnesium (Mg^{2+}), calcium (Ca), kidney, and liver function tests, white blood cells, Hemoglobin, hematocrit, and glucose (Glu).

Methods

The study was executed in two phases: The preparatory phase and the implementation phase.

Preparatory phase

- Seeking permission to conduct the study was obtained by the researcher from the head of ICUs units after an explanation of the aim and nature of the study.
- Construction for data collection tools after extensive literature review.
- Content validity: the tools were tested for content related validity by a jury of 5 specialists in the field of critical care nursing and critical care medicine from Assiut university then the tools were designed in their final format.
- The reliability was tested for tool one: "patient's assessment tool", and tool three: " Acid-base parameters assessment tool" by using Cronbach's alpha (tau-equivalent reliability) coefficient (r= 0.750, 0.749 respectively) which its internal consistency "acceptable",

Pilot study

It was conducted on 10% of the sample in the selected setting to evaluate the applicability and availability of the tools. Also, to estimate the time needed to answer the study tools. then it was modified according to the result of the pilot study.

Ethical consideration

- The research proposal was approved from the Ethical committee of the Faculty
- There was no risk of study subjects during the application of the study.
- The study followed common ethical principles in clinical research.
- Verbal consent was obtained from the legal guardian of all patients participated in the study, after explaining the nature and the purpose of the study.
- Confidentiality and anonymity were assured.
- The patient or legal guardian had the right to refuse to participate and or withdraw from the study without any rationale at any time.
- The patient was assured that the data of this research was not be reused without second permission

Implementation phase

- Data were collected from adult critically ill patients managed in intensive care units at Assiut university hospital between October 01, 2018, and June 30, 2019. The purpose of the study was explained to all conscious patients and to the relatives of the comatose patients prior to data collection.
- Once the permission was granted to proceed with the proposed study, the researcher's proposal was submitted to the research committee at Assuit University, the name of the patients who have admitted to each unit, and who met the criteria was obtained from the responsible nurse in each unit.
- On admission, demographic data (age, gender) were recorded. Medical and clinical data including diagnosis, causes of ICU admission, type of admission, place prior to admission, past history, presence of comorbidities, and history of severe organ system insufficiency or immunocompromised were calculated. Vasopressor used, fluid management, renal replacement requirements, and mechanical ventilation requirements were also recorded from the patient's recorded using tool 1 (part I). This was done by asking and reviewing the patient's file. Classical vital signs were closely monitored and recorded.
- APACHE II score was calculated based on the worst values recorded during the first 24 hrs. of admission. The online APACHE II Calculator was used to calculate the corresponding score for each patient. The worst values were obtained for temperature, mean arterial pressure (MAP), heart rate, respiratory rate, PaO2 and/or A/a gradient, serum HCO3, arterial pH, serum sodium, serum potassium, serum creatinine, hematocrit, and WBCs. The presence of acute renal failure, the Glasgow Coma Score, the presence of chronic organ insufficiency, and the patient's age was also noted. Surgical status was also obtained and documented.
- Venous blood was obtained for the routine tests using samples of separated plasma for concentrations of sodium (Na), potassium (K), magnesium (Mg2+), albumin (Alb), plasma creatinine, blood urea nitrogen (BUN), protein, and bilirubin by a fully automated

analyzer (Dimension RxL Max; Siemens Healthcare Diagnostics, U.S.A.).

- Acid-base homeostasis or imbalance was judged according to the sample taken upon arrival by taking into consideration the expected compensatory response. The initial ABGs reports of each patient were analyzed by the bedside approach.
- Bedside approach: Each report's pH, pCO2, bicarbonate, and BE were noted. The observed pH indicated whether the primary Acid-Base Disorder (ABD) was compensated (by comparison with the normal range of pH: 7.35-7.45). The direction of change of pH from mean denoted the primary disorder. If pH and pCO2 moved opposite and bicarbonate and pCO2 moved in the same direction, the result was primary respiratory disorder with a compensatory metabolic response. If pH, pCO2, and bicarbonate moved in the same direction, the result was primary metabolic disorder with a compensatory respiratory response. If pCO2 and bicarbonate moved opposite with pH at mean, within range or abnormal, the disorder was mixed. The direction of pH shift from mean indicated the stronger component.
- Regarding the degree of compensation: If a primary acidosis or alkalosis is present, the expected degree of compensation can be predicted using the following equations.

Simple acid-base disorder

- Metabolic Acidosis: Expected PCO2 = 1.5 x (HCO3- + 8 ± 2).
- Metabolic Alkalosis: Expected PCO2 = 0.9 x (HCO3- + 16 ± 2).
- If measured PCO2 is less than expected PCO2 then respiratory alkalosis is present.
- If measured PCO2 is greater than expected PCO2 then respiratory acidosis is present.
- Respiratory Acidosis: Plasma HCO3 will increase by 1 meq / L for each 10 mm Hg increase PCO2 in acute cases and 4 meq. / L in a chronic case
- Respiratory Alkalosis: Plasma HCO3 will increase by 2 meq / L for each 10 mm Hg decrease PCO2 in acute cases and 5 meq. / L in a chronic case

Mixed acid-base disorders

A lack of appropriate compensation for a single acid-base disturbance suggests a mixed acid-base disorder.

- During hospitalization and at discharge or before death, other clinical data at admission were collected from the patient's medical admission sheet.
- Daily routine follows up included laboratory tests, as well as the physical examination, which was done during their ICU stay.
- Finally**,** the researcher assessed the studied patients in the previously mentioned setting for ICU discharge criteria and monitoring of the outcomes by recording the following:

- Discharge to home.
- Discharges against medical advice (DAMA).
- Transferred to another unite.
- Transferred to another hospital.
- Patient dies (death).
- The length of patients' stays (LOS) in ICU.

Statistical analysis

The statistical analysis was carried out using SPSS version 20. The collected data were tabulated and analyzed by using frequency distribution, the percentage for qualitative variables. Mean and standard deviation for quantitative variables. The chi-square test and ANOVA test are used to determine significance for the non-parametric variable. P-value <0.05 was considered indicating statistical significance.

Results

Table (1): Baseline personal and Clinical data characteristics of the studied patients (No. =80).

Personal and clinical data characteristics	No.	%
Age:		
(Mean ± SD)	41.88±13.39	
Sex:		
Male	55	68.8
Female	25	31.2
Reason for admission ICU		
Respiratory disorders	21	26.3
Shock	6	7.5
Trauma	22	27.5
Sepsis/ infection	3	3.8
Post-operative	17	21.3
Post cardiac arrest	8	10.0
Renal disorders	3	3.8
Type of admission:		
Medical	56	70.0
Elective surgery	10	12.5
Emergency surgery	14	17.5
Source of admission:		
Ward	7	8.8
Emergency unit	47	58.8
Operation theater	24	30.0
Another hospital	2	2.5
Unit of admission:		
Trauma ICU	14	17.5
General ICU	39	48.8
Intensive care unit	27	33.8
comorbidities:		
No comorbidity	42	52.5
Neurological disease	9	11.2
Liver disease	4	5.0
Renal disease	2	2.5
Respiratory disease	8	10.0
Hypertension	14	17.5
Diabetes mellitus	13	16.3
Cancer	4	5.0

ICU: intensive care unit.

Table (2): Continue baseline personal and Clinical Data of the studied sample (No. =80).

Personal and clinical data characteristics	No.	%
Mechanical ventilation on admission	55	68.8
Vasopressors on admission	29	36.3
Renal failure on admission	4	5.0
GCS score on admission:		
Mean ± SD	8.37 ± 4.12	
Length of ICU stay:		
Mean ± SD	10.90 ± 7.86	
Discharge criteria:		
Transferred to another unit	57	71.3
Discharge against medical advice	3	3.8
Patient died	20	25.0

GCS: Glasgow Coma Scale, ICU: intensive care unit.

Table (3): Distribution of studied patients in relation to APACHE II score on admission and Comparison between survivors and non-survivors (No. =80)

Apache Ii Score	All patients (n=80)		Survivors (n= 60)		Non-survivors (n= 20)		P-value
	No.	%	No.	%	No.	%	
≤ 9	10	12.5	10	16.7	0	0.0	0.011*
10-19	33	41.25	28	46.7	5	25.0	
20-29	32	40.0	18	30.0	14	70.0	
≥ 30	5	6.25	4	6.7	1	5.0	
Apache Ii Score Mean ± SD	18.56 ± 6.891		16.92 ± 6.67		23.50 ± 5.00		<0.001*

APACHE II: Acute physiology and chronic health Evaluation
** Significant difference (P < 0.05). - ANOVA Test – Chi-square test*

Table (4): Distribution of studied patients in relation to laboratory investigation. (No. =80).

Variables	1st day	2nd day	3rd day	4th day	5th day	P.value
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
WBCs (10^3/µL)	14.48 ± 8.84	12.37 ± 6.54	12.21±5.99	11.50 ± 4.82	10.49 ± 4.89	0.002*
HB (g/dL)	11.15 ± 3.09	10.29 ± 2.86	10.20 ± 2.31	10.15 ± 2.19	10.00 ± 2.04	0.038*
HCT %	34.53± 9.01	32.24 ± 8.37	32.44 ± 7.65	31.88 ± 7.43	31.75 ± 6.44	0.158
S. Sodium (mEq/L)	138.31± 8.05	138.81± 6.64	138.95 ± 6.41	138.37± 7.01	138.54±9.09	0.979
S. Potassium (mEq/L)	4.03 ±0.78	3.97 ± 0.76	3.91 ± 0.64	3.86 ± 0.69	4.05 ± 0.92	0.494
S. Calcium (mg/dL)	7.75 ± 1.10	7.88 ± 1.01	7.99 ± 0.99	7.98 ± 0.75	8.05 ± 1.10	0.362
S. magnesium (mg/dL	1.92 ± 0.42	2.02 ± 0.49	1.97 ± 0.45	2.01 ± 0.41	1.96 ± 0.40	0.625
BUN (mg/dl)	10.08 ± 7.00	11.38 ± 8.00	10.81 ± 8.68	10.31 ± 8.92	10.71 ± 12.55	0.917
Creatinine µmol/L	118.70 ± 114.7	126.76 ± 131.67	120.31 ± 157.51	112.37 ± 151.10	110.25 ± 163.17	0.956
T. bilirubin (mg/dL)	0.72 ± 0.49	0.75 ± 0.46	0.73 ± 0.46	0.80 ± 0.50	0.76 ± 0.56	0.881
D. bilirubin (mg/dL)	0.28 ± 0.27	0.29 ± 0.27	0.30 ± 0.25	0.30 ± 0.26	0.34 ± 0.40	0.731
Protein (g/dl)	5.63 ± 1.02	5.64 ± 0.86	5.64 ± 0.89	5.60 ± 0.87	5.80 ± 0.80	0.650
Albumin (g/dL)	2.25 ± 0.75	2.17 ± 0.63	2.07 ± 0.59	2.02 ± 0.59	1.95 ±0.57	0.029*
Blood sugar (mg/dL)	204.62 ±91.38	187.12 ± 75.52	167.81 ± 53.17	159.00 ± 55.64	152.42 ± 46.43	< 0.001*

** Significant difference (P < 0.05). - ANOVA Test*

WBCs: White blood cells, HB: hemoglobin, HCT: hematocrit, BUN: blood urea nitrogen.

Table (5): Distribution of studied patients in relation to arterial blood gases parameter values. (No. =80).

	1st day	2nd day	3rd day	4th day	5th day	P.value
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
PH	7.34 ± 0.13	7.42 ± 0.08	7.46 ± 0.05	7.44 ± 0.07	7.41 ± 0.09	< 0.001*
$PaCO_2$	39.63 ± 18.40	37.52 ± 16.61	39.10 ± 10.03	38.87 ± 15.13	42.00 ± 14.39	0.447
PaO_2	98.23 ± 56.92	109.90 ± 48.93	99.21 ± 42.28	103.73 ± 42.62	94.08 ± 31.00	0.225
HCO_3	22.04 ± 8.83	24.05 ± 8.13	26.28 ± 7.61	26.22 ± 8.20	26.50 ± 7.56	0.003*
B.E	-3.54 ± 9.30	-0.14 ± 7.73	2.89 ± 6.59	2.53 ± 8.45	2.07 ± 7.81	< 0.001*
FiO_2	46.67 ± 15.90	39.92 ± 11.41	38.36 ±12.82	36.97 ± 12.81	32.83 ± 18.56	< 0.001*
SaO_2	90.58 ± 14.19	95.01 ± 7.84	95.19 ± 6.89	95.97 ± 5.33	95.02 ± 5.47	0.001*
Lactate	2.99 ± 2.94	2.10 ± 1.33	1.80 ± 1.31	1.81 ± 1.64	2.18 ± 1.95	0.001*

** Significant difference (P < 0.05).* *- ANOVA Test*

PaCo2: partial pressure of carbon dioxide, PaO2: partial pressure of oxygen, HCO3: Bicarbonate, BE: Base excess, FiO2: Fraction of inspired oxygen, SaO2: Oxygen saturation

Table (6): Frequency distribution of studied patients in relation to types of acid-base disorders on admission until 5th day. (No. =80)

Variables	Yes		No		P.value
	F	%	F	%	
Simple ABDs (single)					
Metabolic acidosis	21	26.3	59	73.8	< 0.001*
Metabolic alkalosis	27	33.8	53	66.3	< 0.001*
Respiratory acidosis	26	32.5	54	67.5	0.002*
Respiratory alkalosis	59	73.8	21	26.3	0.004*
Mixed ABDs					
Metabolic acidosis with respiratory acidosis	12	15.0	68	85.0	< 0.001*
Respiratory acidosis with metabolic alkalosis	2	2.5	78	97.5	< 0.001*

** Significant difference (P < 0.05).* *– Chi square test*

ABD: Acid-base disorders

** F: frequency of acid-base disorders on admission until the 5th day.*

Table (1): Demonstrated that the patient's age ranged from 18 to 60 years old with a mean age of (41.88 ± 13.39). more than two-thirds of the patients were male (68.8%) compared to the females (31.2%).

The most common reason for ICU admission was trauma (27.5%), more than two-thirds of patients admitted for medical management (70.0%), more than half of patients admitted from the emergency room(58.8%), nearly to half of patients admitted to General ICU (48%).

Table (2): Demonstrated that most patients (52.5%) had no identifiable comorbidities prior to ICU admission. Of those with comorbidities, hypertension (17.5%) and diabetes (16.3%) were the two most common underline diseases. Regarding mechanical ventilation more than two-thirds of patients (68.8%) were needed mechanical ventilation at the time admission, more than a third of patients received vasopressors on admission (36.3%), only four patients (5.0%) had a renal failure on admission. In relation to the GCS score on admission, the mean score was (8.37 ± 4.12). As regards the length of ICU stay the mean was (10.90 ± 7.86). Concerning discharge criteria more than two-thirds of patients (71.3%) were improved and transferred to another unit. Almost one-fourth of patients in the current study died during their ICU stay.

Table (3): This table shows the distribution of the studied sample in relation to the APACHE II score and Comparison between survivors and non-survivors. It revealed that majority of patients had scored less than 20 and more than one-third of patients (41.25%) had a score between 10-20, while the Mean ± SD was (18.56 ± 6.89) Also, this table shows Statistically significant differences were seen in between survivors and non-survivors confirmed by (APACHE P= < 0.001).

Table (4): This table illustrates the mean of hemodynamic parameters among studied patients from the 1st until the 5th day. It revealed that WBC elevated than normal on 1st, 2nd, 3rd days of admission the mean was (14.48 ± 8.84, 12.37 ± 6.54,

12.21±5.99) respectively with Statistically significant differences (P= 0.002). Notable decrease in hemoglobin on 2nd, 3rd, 4th, and 5th days the mean was (10.29 ± 2.86, 10.20 ± 2.31, 10.15 ± 2.19, 10.00 ± 2.04) respectively with Statistically significant differences (P= 0.038). Serum calcium was slightly decreased below the normal level on the 1st, 2nd, 3rd, and 4th days of admission the mean was (7.75 ± 1.10, 7.88 ± 1.01, 7.99 ± 0.99, 7.98 ± 0.75). Creatinine level was higher than normal values on the 1st, 2nd, 3rd days of admission and slightly above the borderline on the 4th day, the mean was (118.70 ± 114.70, 126.76 ± 131.67, 120.31 ± 157.51, 112.37 ± 151.10) respectively. Remarkable decrease of serum albumin was observed for almost all the patients from 1st day to 5th day the mean was (2.25 ± 0.75, 2.17 ± 0.63, 2.07 ± 0.59, 2.02 ± 0.59, 1.95 ±0.57) respectively with Statistically significant differences (P= 0.029). Noticeable increase in blood sugar above the borderline on the 1st day of admission the mean was (204.62 ± 91.38) with Statistically significant differences (P= < 0.001).

Table (5): This table illustrates the mean of arterial blood gases parameters values among studied patients from the 1st until the 5th day. It revealed that there was a significant decrease in pH value on the 1st day of admission the mean was (7.34 ± 0.13), while pH tends to increase to alkalotic side on 3rd day (7.46 ± 0.07) with Statistically significant differences (P= < 0.001) Concerning HCO3 remained on the borderline of the upper limit with Statistically significant differences (P= 0.003). Base excess show decrease on the 1st day of admission (-3.54 ± 9.30), while showing a slight increase in 3rd and 4th days respectively (2.89 ± 6.59, 2.53 ± 8.45) with Statistically significant differences (P= < 0.001).concerning to the fraction of inspired oxygen (FiO2) there was Statistically significant differences confirmed by (P= < 0.001). regarding oxygen saturation (SaO2) there was a marked decrease on the 1st day of admission with Statistically significant differences (P= 0.001). Regarding to lactate level, there was marked elevation on the 1st, 2nd, and 5th days (2.99 ± 2.94, 2.10 ± 1.33, 2.18 ± 1.95). respectively with Statistically significant differences (P= 0.001).

Table (6): This table shows types of acid-base disorders, it revealed that respiratory alkalosis was the predominant disorders of simple acid-base disorders (73.8 %) with Statistically significant differences (P= 0.004) followed by metabolic alkalosis and respiratory acidosis (33.8 %), (32.5 %) with Statistically significant differences (P= <0.001), (P= 0.002) respectively, while the metabolic acidosis was fewer disorders observed with Statistically significant difference(P= <0.001). Among the mixed acid-base disorders, the common combinations were mixed metabolic acidosis with respiratory acidosis (15.0%), followed by the mixed respiratory acidosis with metabolic alkalosis (2.5%). with Statistically significant difference (P= < 0.001), (P= < 0.001) respectively.

Discussion

Acid-base homeostasis is crucial to the normal function of the body. If acid-base disorder (ABD) is not detected timely, it may lead to serious or potentially fatal conditions. It is natural to expect a high incidence of acid-base disorders (ABD) in critical illness **(Song et al., 2012)**.

Baseline personal and clinical characteristics of patients

In the present study, our sample size included eighty patients admitted to ICU at Assiut university hospital. Patient's ages ranged from 18 to 60 years old with a mean age of (41.88±13.39). Studies conducted with critical patients in intensive care units and emergency departments by **(Praveen et al., 2014)** & **(Köse et al., 2014)** reported that the mean ages of patients (56.7±19.1) years and (60.7±17.17) years respectively.

As regard gender, it has been noticed that more than half of the patients were males. In similar studies, acid-base disorders were more common in males **(Shreewastav et al., 2019) & (Köse et al., 2014).** Concerning reason for ICU admission, the present study revealed that the most common reason for ICU admission was trauma this finding congruence with cohort study conducted by **(Ho et al., 2016)** where they documented that isolated head trauma and multiple trauma were the Major reason for ICU admission. Actually, it depends on the type of ICU; the most common cause of admission is trauma in ICU trauma. However, other medical diseases were the most common causes of admission in medical ICUs.

Also, our data revealed that more than two-thirds of patients admitted for medical management this result in agreement with **(Grover et al., 2014)** and **(Radwan et al., 2013)** study where they have found that most of the patients were admitted for medical management of acute illnesses and only a minority of patients were admitted for planned surgery. In addition, our data shows that more than half of patients admitted from the emergency room, The present results are in the same line with **(Amalraj et al., 2017)** who reported that most of their patients were admitted to ICU directly from the emergency room and a few were admission in ICU from the wards/rooms.

Regarding comorbidities, our present study shows that the majority of patients had no identifiable comorbidities prior to ICU admission, this finding

congruence with a prospective observational study by**(Sulieman, et al., 2018)** who found that majority of patients had no comorbidities before admission to the ICU. Of those with comorbidities, the most common were hypertension and diabetes. The present results are in line with a retrospective study by **(Chao, et al., 2017)** who documented that hypertension and diabetes mellitus were the two most common underlying diseases. Also, the present study revealed that more than two-thirds of patients were needed mechanical ventilation at the time of admission and more than a third of patients received vasopressors on admission. Our results are in the same line with prospective cohort study which involved patients admitted to the medical ICU of Siriraj Hospital which conducted by **(Tongyoo, et al., 2018)** who found that the majority of patients were required mechanical ventilation on admission, while more than two-thirds were received vasopressors on admission to the ICU. Only four patients had a renal failure on admission to ICU. This finding on contrary to **(Abd Elhafeez, et al., 2017)**who found that about forty percent of the patients admitted to ICU had acute kidney injury (AKI) on admission.

Regarding the length of ICU stay (LOS), the present study showed that the mean LOS was (10.9 ± 7.8 days). These findings supported by **(Sulieman, et al., 2018)** who conducted a study on one hundred patients in the ICUs of two government tertiary care hospitals in Khartoum, Sudan. They reported that the mean length of ICU stay was (10.0 ± 7.2 days) which is in the same line with our finding. Concerning discharge criteria, more than two-thirds of patients were improved, and transferred to other units in stable condition. Twenty patients (one fourth) of the sample in the current study died during their ICU stay, in the same line prospective cohort study conducted by **(Zampieri, et al., 2014)** who found that about one-fourth of patients died in the ICU.

Regarding APACHE II on admission, the present data shows that majority of patients had scored less than 20 and more than one-third of patients had a score between 10-20 this data on contrary with a prospective observational study by **(Kiran et al., 2015)** who documented that the majority of patients had APACHE II score of >20 and minority of patients had APACHE II score between 18 and 20.

Type of acid-base disorders

Acid-base disorders (ABD) reflect the primary disorder and themselves lead to potentially life-threatening complications. The ABDs may be of simple (single) or primary type with a secondary compensatory response or may be of mixed type-occurrence of two or more independently existing primary ABD in the same patient. The laboratory diagnosis should always be correlated with clinical details. The cause of individual acidemia or alkalemia should be explored in each case **(Ghatak, et al., 2016).**

In the present study, we noticed that majority of patients with the acid-base disorder had simple (single) acid-base disorders (SABD). Only a few patients had mixed acid-base disorders. Of those with simple acid-base disorders, respiratory alkalosis was the most common disorder observed in our study, the results of the present study agree with **(Hamdi, et al., 2016)** who reported that the most common acid-base abnormality observed in critically ill patients is respiratory alkalosis with no discrimination between genders. These results also in agreement with another study conducted by **(Praveen, et al., 2014)** who reported that the most common simple acid-base disorder was respiratory alkalosis. **(Shreewastav et al., 2019).** Their findings were also similar to our study, as they found that the respiratory alkalosis was the most common type of simple ABD.

The reason that most simple acid-base disorders were respiratory alkalosis could be explained by multiple psychological and pathophysiological mechanisms that can stimulate respiration. Hypocapnia is significantly correlated with adverse outcomes in a variety of critical illnesses. The commonest type of respiratory alkalosis which indicated that respiratory compensatory mechanisms would play a major role. Some iatrogenic factors should be considered in addition to body compensatory mechanisms. **(Ronco, et al., 2019)** & **(Song, et al., 2012)**.

Another prevalent simple acid-base disorder observed frequently in critically ill patients was metabolic alkalosis, this result in agreement with the study published by **(Mæhle, et al., 2014)** who has reported that metabolic alkalosis was a very common occurrence in ICU patients. The least common simple acid-base disorders observed in our study were respiratory acidosis and metabolic acidosis respectively as we noticed few patients presented in a critical condition having acidosis whether respiratory or metabolic.

Regarding mixed acid-base disturbances in this study, we identified a few patients with mixed type of acid-base disorder. The common combinations were metabolic acidosis with respiratory acidosis and respiratory acidosis with metabolic alkalosis. Our findings are in contrast with the study conducted by **(Rajendran, et al., 2019),** who found that mixed acid-base disorders are the most common disturbances in the intensive care setup. Another cross-sectional study conducted by **(Ghatak, et al., 2016)** shows a high prevalence of mixed type acid-base disorders in critically ill patients admitted in the ICU of a tertiary care teaching hospital.

The high prevalence of hidden cases of mixed acid-base disturbances can be recognized by concomitant analysis of acid-base and electrolyte parameters, including anion gap calculation which was limited in our study. Indeed, **(Szrama, & Smuszkiewicz, 2016)** found a systematic approach that proves that patients may suffer from mixed arterial blood gas disorders hidden under normal values of standard base excess (SBE) and pH which is unrevealed by the traditional approach.

Another prospective study confirmed the previously mentioned study conducted by **(Ghatak, et al., 2016).** They concluded that a systematic approach was more effective in diagnosing mixed acid-base disorders as compared with the traditional approach. The significant increase in the incidence of mixed disorders by the systematic method was explained by its multistep comprehensive approach. It evaluated anion gap, degree of compensation (whether appropriate in a simple disorder or not indicating mixed disorder), corrected anion gap for hypoalbuminemia, delta ratio, etc. The hidden primary co-existent disorder became unmasked in this approach.

An additional study by **(Moviat, 2013)** concluded that ICU patients with an apparently normal acid-base state according to traditional criteria have an underlying mixed metabolic acid-base disorder characterized by acidifying effects of a low SID (Strong Ion Difference) (due to hyperchloremia) and high SIG (Strong Ion Difference) (both acidifying effects) and the alkalizing effect of a low level of the weak acid albumin.

Conclusions

1. Based on our findings of the current study, it can be concluded that acid-base disorders are common in critically ill patients presenting at the ICU.
2. Respiratory alkalosis (primary hypocapnia) was the most frequent acid-base disturbance encountered in patients who are critically ill. Mixed ABD was the lest frequently observed case.
3. Critically ill patients are at risk for acid-base disorders due to primary disease, chronic disease, presence of comorbidity, side effects of some drugs used, or iatrogenic causes.

Recommendation

1. Identify patients at high risk of worse outcomes and, potentially, to increase the intensity of the therapeutic approach.
2. Acid-base disorders should be monitored closely, diagnosed early, and managed correctly during hospitalization and iatrogenic factors should be avoided.

Limitations

The main limitation of our study is that we did not evaluate the anion gap because serum chloride level check was not a routine practice at the hospital. This limitation did not let us categorize the intensity of anion gap metabolic acidosis/alkalosis (i.e. high vs. normal). It also limited us to reach the appropriate diagnosis by uncovering the concurrence of mixed metabolic acid-base disorders in patients with high anion gap acidosis.

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