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Arterial Blood Gases as an Indicator of Early ICU Admission in Chest Trauma Patients

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ABSTRACT

Background: Trauma is injury to living tissue caused by an extrinsic agent. Trauma is a Greek word which means body injury. Blunt chest trauma causes 25% of traumatic deaths. It is commonly associated with multiple organ damage which leads to catastrophic patient outcome. Blunt chest trauma is more common than penetrating chest trauma. Arterial blood gas (ABG) studies report the degrees of acidemia, hypercarbia, and hypoxemia, which depend on cardiopulmonary status at the time of collection. **Objective:** To determine the value of ABG measurements in patients with blunt chest trauma and its role in prognosis of different outcomes.

Patients and Methods: This study included 100 patients arrived to Emergency Department (ED) in Emergency Hospital-Mansoura University during the period from 1-8-2019 to 1-8-2020. Patients were divided to subtypes according to ward or ICU admissions and presence or absence of lung injury. Length of hospital stay as outcome was also reported.

Results: ABG and combined ABG measurements are strongly reflecting the clinical situation of chest trauma patients. It can predict longer length of hospital stay. PCO_2 is more sensitive than $HCO3^-$ in prediction of ICU admission in chest trauma patients. SaO_2, combined ABG analysis had higher sensitivity in prediction of ICU admission in chest trauma patients. $HCO3^-$ level and combined ABG were statistically significant in prediction of lung injury among studied patients with high specificity.

Conclusion: ABG values and combined ABG values seemed to have a promising role in determination of patients admitted to ward versus others admitted in ICU.

Keywords: Advanced Trauma Life Support, Emergency medical system, Focused assessment with sonography for trauma.

INTRODUCTION

Trauma-related mortality accounts for 9% of deaths in all age groups and most cases involve blunt injuries. Multiple traumas are the main cause of emergency admission, accounting for approximately 16% of global medical expense **(1)**. Chest trauma is one of the most common injuries suffered by poly trauma patients, with an incidence of 45%–65%. This type of trauma, which is usually caused by a high-energy blunt force, is associated with mortality rates as high as 60% **(2)**. Chest injury was found to cause death in 20%–25% of multiple trauma patients. Thoracic trauma is, therefore, important in the overall management of multiple injured patients and may require a longer stay in the Intensive Care Unit (ICU) and use of mechanical ventilation **(3)**. In addition, trained multidisciplinary teams and well-equipped facilities play critical roles in reducing the rate of mortality within a few hours of trauma injury **(4)**.

Though multiple studies have been done to evaluate factors that predict morbidity and mortality in thoracic trauma, few have developed into scoring systems. A prognostic scoring system makes it easier to manage by directing resources. Improved outcomes and decreased hospital stay were reported following score and protocol-based interventions in trauma victims **(5)**.

The need for a universal system for thoracic trauma is justified to identify critical factors, to predict patient outcomes, urgent need for intervention, requirement of intensive care, and to communicate with the family **(6)**. The available thoracic trauma scores are Wagner score, Abbreviated Injury Scale chest (AIS), Lung Injury Scale, Pulmonary Contusion score (PCS), or Rib-Score, Thoracic Trauma Severity Score (TTSS) and modified early warning signs (MEWS) scoring system **(7)**. Due to difficult applicability of some scores, lack of significance for predicting outcome or resource limitation, there is no universal scoring system **(8)**.

There is evidence to support routine blood gas analysis for base deficit and metabolic acidosis evaluation in trauma patients suspected on initial history and physical examination as being at risk of serious injury. However, the decision as to whether to obtain a venous or arterial blood gas is best determined by the needs of the individual patient with consideration of arterial oxygen saturation and tissue perfusion status **(9)**.

The aim of this study was to determine the value of ABG measurements in patients with blunt chest trauma and its role in prognosis of different outcomes as length of hospital stay, ward or ICU admissions and lung contusion.

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PATIENTS AND METHODS

This study was a prospective observational study, which was done on 100 patients arrived to emergency department (ED) in Emergency Hospital-Mansoura University during the period from 1-8-2019 to 1-8-2020.

Inclusion criteria: All adult patients over 18 years old with poly-trauma or blunt trauma to chest and thoraco-abdominal area from both genders are included in the study.

Exclusion criteria: Shocked patients whom were intubated, patients that had pulmonary disease or heart diseases, patients needed urgent surgery or died before CT chest, penetrating chest injuries, pregnant females, patients who do not want to participate in the study and patients below 18 years old.

All patients were subjected to careful history including age, gender, mode and time of trauma, arrival and resuscitation. Evaluation of the patients at the trauma room including:

1- Clinical examination:

A. Primary survey including:

- Airway.
- Breathing.
- Circulation.
- Disability: Glasgow coma scale (GCS).
- Exposure of the patient to detect other injuries.

B. Secondary survey:

- Full clinical examination of all body.
- GCS on admission after primary respiratory and hemodynamic stabilization.

2. Laboratory and radiological investigations

Full laboratory analysis including:

- Arterial blood gases (ABG) in room air, PO_2, PCO_2 and base deficit.
- Oxygen saturation, hypoxemic index.
- Combined ABG calculations**:**

Additionally in our study we determined the alveolar-arterial O_2 gradient ($AaDO_2$) and its augmentation. The calculation of $AaDO_2$ was equal to the following: $AaDO_2$=150-1.25$PaCO_2$-PaO_2. The $PaCO_2$ reflects CO_2 partial pressure in the blood passing in the arteries while the PaO_2 equals to the O_2 partial pressure in the blood in the arteries. The ABG measurements were done in room air [10]**.** The alveolar PO_2 (PAO_2) was calculated as the following equation: PAO_2=PiO_2- $PACO_2$/RER. RER refers to the respiratory exchange ratio, which is about 0.8 while the PiO_2 reflects the O2 partial pressure in gas, which reaches the alveoli in the inspiration phase (nearly 150 mm Hg) and $PACO_2$ refers to the alveolar PCO_2. Consequently, the utilized equation in our study turned to be PAO_2=150- $PaCO_2$/0.8 [11]**.** In the current study, $AaDO_2$ augmentation calculation was done with the consequent equation: $AaDO_2$ augmentation = $AaDO_2$-estimated normal gradient (ENG). The ENG was measured with the following equation (Age/4) + 4. The P/F is the ratio between the PaO_2 and the fraction of oxygen detected in the inspiration phase. The calculation of the estimated normal PaO_2 was carried out from the following equation: 100- Age/3. In addition, The PaO_2 Deficit = estimated normal PaO_2-ABG analysis of PaO_2 [12]**.** Additionally, The a A O_2 tension ratio refers to the ratio between the O_2 partial pressure in the blood in the arteries and alveolar PO_2, normally it ranges between 0.75 and 1. Furthermore, in our study, the measurement of hypoxemia was determined by the following factors; PaO_2, O_2 saturation, PaO_2 Deficit, P/F, and a- A O_2 tension ratio [13]**.**

- Routine blood investigations, which included the following tests: Complete blood count (CBC), serum creatinine and GFR. Radiological analysis including abdominal and chest ultrasound (US), chest X ray and CT chest.

3. Outcomes of our study included:

- Primary outcome: Mortality or survival within one week.
- Secondary outcomes: Patient admitted to word or ICU and hospital stay.

Ethical consideration:

Study protocol was approved by Institutional Review Board (IRB). Written Informed consent was attained from each subject sharing in the study. Confidentiality and personal privacy were considered throughout the period of study.

Statistical analysis:

Recorded data were analyzed using the statistical package for social sciences, version 20.0 (SPSS Inc., Chicago, Illinois, USA). Quantitative data were expressed as mean ± standard deviation (SD). Qualitative data were expressed as frequency and percentage. Independent-samples t-test of significance was used when comparing between two means. Chi-square (x^2) test of significance was used in order to compare proportions between two qualitative parameters. The confidence interval was set to 95% and the margin of error accepted was set to 5%. The p-value was considered significant as the following: P-value ≤ 0.05 was considered significant. P-value ≤ 0.001 was considered as highly significant. P-value > 0.05 was considered insignificant.

RESULTS

Patients were divided to subtypes according to ward or ICU admissions and presence or absence of lung injury. Demographic characteristics of the included cases, diagnosis of the included patients, outcome distribution among the included cases, and arterial blood gases distribution among included cases were stated in table 1, 2, 3 & 4 respectively.

Table (1): Demographic characteristics of the studied cases.

	N=100	%
Age/years Mean ± SD	38.58 ± 14.44 (18.0-75.0)	
Sex		
Male	75	75.0
Female	25	25.0

Table (2): Outcome distribution among studied cases.

	N=100	%
Outcome		
Ward	57	57.0
ICU	43	43.0
Length of hospital stay: Mean ± SD Median (Min-Max)	5.03 ± 3.56 4.0 (2.0-21.0)	
Mortality	0	0.0

Table (3) demonstrated that ABG values and combined ABG values were statistically significant in determination of which patients will be admitted to ward and others admitted in ICU.

Table (3): Comparison of ABG mean values according to need of ICU admission among studied cases.

	Ward N=57	ICU N=43	test of significance
PH	7.39 ± 0.04	7.32 ± 0.12	t=4.27 p<0.001*
PCO_2	38.87 ± 3.65	48.17 ± 4.99	t=4.51 p<0.001*
PO_2	76.22 ± 11.66	44.54 ± 5.22	t=11.79 p<0.001*
HCO_3	22.84 ± 2.07	23.80 ± 2.66	t=2.05 p=0.04*
SaO_2	94.91 ± 2.71	74.71 ± 11.67	t=12.64 p<0.001*
Aa Do_2	25.21 ± 1.60	45.25 ± 4.24	Z=5.58 p<0.001*
Aa DO_2 augmentation	11.37 ± 1.95	31.96 ± 4.51	Z=5.64 p<0.001*
P/F	3.61 ± 0.55	2.11 ± 0.72	t=11.79 p<0.001*
PaO_2 deficit	10.58 ± 2.16	42.92 ± 6.14	Z=11.43 p<0.001*
a-A O_2 tension ratio	0.758 ± 0.144	0.579 ± 0.027	Z=2.08 p=0.04*

Student t test * statistically significant all parameters described as mean ± SD
: Mann Whitney U test

Table (4) demonstrated that only HCO_3 level in mean ABG calculations was statistically significant between non lung injury and lung injury group, being higher in lung injury group (p = 0.015*).

Table (4): Comparison of mean ABG according to lung injury diagnosis among studied cases.

	Non lung injury N = 4	**Lung injury N = 96**	**test of significance**
PH	7.33 ± 0.04	7.35 ± 0.09	t = 0.540 p=0.590
PCO^2	43.23 ± 9.43	42.85 ± 1.26	t=0.065 p=0.948
PO_2	56.85 ± 4.91	62.84 ± 2.50	t=0.568 p=0.571
HCO_3	20.43 ± 2.41	23.37 ± 2.32	t=2.49 p=0.015*
SaO_2	81.75 ± 17.38	86.41 ± 12.62	t=0.714 p=0.477
Aa Do_2	39.11 ± 7.93	33.60 ± 2.45	z=0.422 p=0.673
Aa DO_2 augmentation	28.74 ± 6.93	19.87 ± 2.82	z=0.809 p=0.418
P/F	2.70 ± 0.18	2.98 ± 0.97	z=0.563 p=0.573
PaO_2 deficit	33.13 ± 0.60	24.13 ± 2.34	z=0.985 p=0.325
a-A O_2 tention ratio	0.58 ± 0.01	0.685 ± 0.04	z=0.563 p=0.573

Table (5) demonstrated that ABG calculations except HCO_3, and combined ABG calculations, which included Aa DO_2, P/F, PaO_2 deficit was statistically significant in relation to length of hospital stay. Length of hospital stay was lower when PH, PCO_2 was normal, PO_2 was high and SPO_2 was high. It was also low when Aa DO_2 was low, P/F ratio was high and PaO_2 deficit was low.

Table (5): Comparison of mean ABG according to length of hospital stay among studied cases.

	Hospital stays <median (4) N=65	**Hospital stays ≥median (4) N=35**	**test of significance**
PH	7.37 ± 0.045	7.32 ± 0.13	t=2.95 p=0.004*
PCO_2	40.27 ± 5.59	47.69 ± 6.33	t=3.329 p=0.001*
PO_2	68.79 ± 8.47	51.09 ± 9.53	t=4.48 p<0.001*
HCO_3	22.97 ± 2.15	23.77 ± 2.72	t=1.62 p=0.108
SaO_2	91.04 ± 9.38	77.27 ± 13.48	t=5.98 p<0.001*
Aa Do_2	30.87 ± 5.48	39.32 ± 6.48	t=2.02 p=0.04*
Aa DO_2 augmentation	17.49 ± 6.44	25.29 ± 6.38	t=1.82 p=0.072
P/F	3.26 ± 0.87	2.43 ± 0.93	t=4.45 p<0.001*
PaO_2 deficit	18.54 ± 1.78	35.55 ± 8.74	t=4.11 p<0.001*
a-A O_2 tension ratio	0.681 ± 0.16	0.681 ± 0.099	t=0.009 p=0.993

Table (6) demonstrated that combined ABG and SaO_2 had the highest specificity in prediction of ICU admission among patients. While combined ABG had the highest sensitivity in prediction of ICU admission among studied patients.

Table (6): Validity of ABG in prediction of ICU admission among studied cases.

	AUC (95% CI)	P	Cut off point	Sensitivity	Specificity
PH	0.724	<0.001*	7.375	67.4%	66.7%
PCO_2	0.732	<0.001*	39.60	72.1%	63.2%
PO_2	0.938	<0.001*	59.05	90.7%	94.7%
HCO_3	0.641	0.016*	22.95	74.4%	49.1%
SaO_2	0.975	<0.001*	88.5	83.7%	98.2%
Combined ABG	0.982	<0.001*	0.527	90.7%	96.5%
Aa Do_2	0.901	<0.001*	41.85	96.5%	74.4%
Aa DO_2 augmentation	0.894	<0.001*	23.285	89.5%	83.7%
P/F	0.938	<0.001*	2.395	98.2%	76.7%
PaO_2 deficit	0.931	<0.001*	29.45	91.2%	85.9%
-A O_2 tension ratio	0.902	<0.001*	0.575	98.2%	83.7%

Table (7) demonstrated that HCO_3 level and combined ABG were statistically significant in prediction of lung injury among studied patients with high specificity.

Table (7): Validity of ABG in prediction of lung injury among studied cases.

	AUC (95% CI)	P	Cut off point	Sensitivity	Specificity
PH	.764	.074	7.355	75.0%	75.0%
PCO_2	0.449	.732	41.2	39.6%	50.0%
PO_2	0.585	.568	36.4	89.6%	50.0%
HCO_3	0.829	.026*	22.1	67.7%	75.0%
SaO_2	0.540	.785	71.5	85.4%	50.0%
Combined ABG	0.896	.008*		93.8%	75.0%

Table (8) showed all values of ABG and combined ABG were statistically significant in prediction of long hospital stay except PH value.

Table (8): Validity of ABG in prediction of long hospital stay (> median value).

	AUC (95% CI)	P	Cut off point	Sensitivity	Specificity
PH	0.602	0.902	7.37	51.4%	76.9%
PCO_2	0.648	0.015*	40.75	62.9%	67.7%
PO_2	0.741	<0.001*	61.6	80.0%	72.3%
HCO_3	0.623	0.043*	22.95	77.1%	47.7%
SaO_2	0.811	<0.001*	90.5	80.0%	76.9%
Combined	0.816	<0.001*		80.0%	78.5%
Aa Do_2	0.711	0.001*	32.935	80.0	64.6
Aa DO_2 augmentation	0.695	0.001*	19.95	80.0	66.2
P/F	0.741	<0.001*	2.925	80.0	69.2
PaO_2 deficit	0.729	0.001*	23.95	74.3	69.2
a-A O_2 tension ratio	0.700	<0.001*	0.605	71.4	72.3

DISCUSSION

Trauma is more common in males than females. Death from trauma is more common in males than females [14]. According to WHO trauma causes about 5.8 million deaths every year and it is the leading cause of death in people aged from 1 to 46 years [15].

A study done in our hospital (Mansoura Emergency Hospital) about Patterns of major injuries after motorcycle accidents in Egypt. About 9% of patients (18 patients) had variable chest injuries. Most of the patients included in the study had combined chest injuries. About 67% of chest trauma patients included in this study were managed conservatively, while 4 patients died. Four patients in the study were admitted to ward, while 10 patients of chest trauma patients were admitted to ICU. Intercostal tube was inserted in 33% of patients and one of them died. The largest number of patients admitted to in ICU in this study had combined chest injuries lung contusion then pneumothorax. There was no significant correlation between kind of chest trauma and the final outcome. This is in agreement with our study results as no patients died in our study, however large number of patients were admitted to ICU [16].

Whole blood is needed for an arterial blood gas sample. The specimen can be extracted through an arterial puncture or acquired from an indwelling arterial catheter. Arterial blood sample should be kept on ice and analyzed as soon as possible to reduce the possibility of erroneous results. Automated blood gas analyzers have rapid results, which can be obtained within 10-15 minutes [17].

ABG results give information about the acid base status, oxygenation (pO_2 and hemoglobin saturation) and CO_2 elimination. It can detect any respiratory or metabolic event, as well as it is necessary in adjusting ventilator setting, pre- and post-intubation, pre- and post-extubation. Furthermore, it can confirm pulse oximetry results and it can detect cardiac events [18]. They are routine investigations in blunt chest trauma. Target $PaCO_2$ is 5.0–5.5 kPa (35–40mmHg) [19]. The use of repeated Hb measurements should be used as a laboratory marker for bleeding, as an initial Hb value in the normal range may mask bleeding. Serum lactate and/ or base deficit measurements are sensitive tests to estimate and monitor the extent of bleeding and shock [20].

Adult patients over 18 years old with poly-trauma, blunt trauma to chest and thoraco-abdominal area from both genders were included in our study. Our study included 75% males and a smaller number of females, which was about 25% of study patients. Our study is in agreement with a study conducted by **Farrath *et al.*** [21], which demonstrated that blunt trauma injuries affect males more than females. Furthermore, the median age of patients with blunt trauma was between 30 to 40 years. The main cause of blunt trauma in this study was road traffic accidents and falls from heights. **Tsai *et al.*** [22] concluded also that blunt trauma is more common in males than females, with same reasons as in our study. Furthermore, a study by **Bellone *et al.*** [23], on ICU admission in blunt chest trauma had same distribution among sex and age group like our study.

About 57 % of patients in our study were admitted to ICU, while 43% were admitted to ward. No one of the participating in our study died. Median length of hospital stay was more than or equal to 4 days. In our study, the admitting diagnosis was hemothorax, which was the commonest then pneumothorax, lung contusion and flail chest. Rib fracture was present in association with other kinds of injuries. Only one patient was presented with flail chest. Our study results are similar to other studies conducted on blunt chest trauma as **Tsai *et al.*** [22] who reported that rib fracture was the most common in most of patients with blunt chest trauma, then hemothorax, pneumothorax, subcutaneous emphysema, flail chest, pneumomediastinum, and mediastinal hematoma**.**

In our study, ABG values and combined ABG values were statistically significant in determination of patients admitted to ward versus others admitted to ICU. Hypoxia, hypercarbia, respiratory acidosis and low P/F ratio were found in patients, which admitted to ICU. According to **Karam *et al.*** **[24]** arterial blood gas value is one of the effective risk assessment tools in predicting morbidity and mortality for patients in chest trauma patients. Arterial blood gases are routine investigations in blunt chest trauma. In agreement with our study, PCO2 values are predictors of respiratory failure, need of intubation and mechanical ventilation **[25].** Little percentage of patients with thoracic trauma develop respiratory failure requiring intubation and ventilator support to correct hypoxia and hypercapnia **[26].** On the other hand, prehospital intubation is needed in 35 to 58% of severely injured patients **[27].** Severely injured patients usually need intensive care therapy irrespective of accompanying thoracic injuries. Organ dysfunction and multiple organ failure (MOF) can easily develop in patients with severe thoracic trauma **[28].**

In our study, length of hospital stay was lower when PH, PCO_2 was normal, PO_2 was high and SaO_2 was high. It was also low when Aa Do_2 was low, P/F ratio was high and PaO_2 deficit was low. However, it was more than 4 days with hypoxemia, respiratory acidosis and hypercarbia. It was longer also in patients with reverse values in combined ABG analysis as with high Aa Do_2, low P/F ratio and high PaO_2 deficit. This explains that ABG and combined ABG measurements are strongly reflecting the clinical situation of the patients. This is also in agreement with the studies that reported that ABG measurements are strong predictive tools of patients' morbidity and mortality **[24, 25].**

Our study is different from a study by **Tsai *et al.*** **[22],** who reported that ABG values (pH, PaO_2, $PaCO_2$, HCO_3, and SaO_2) were not statistically significant among blunt chest trauma patients admitted to ICU and were divided into survivors and non-survivors. Furthermore our study was different from **Tsai *et al.*** **[22],** as no patient died from ICU admitted patients in our study. However, our study was in accordance with Tsai ***et al.*** **[22]** as all patients, which were admitted to ICU had respiratory acidosis, metabolic acidosis, hypoxia and hypercapnia. However, hypoxia, hypercapnia, metabolic and respiratory acidosis were higher in non-survivors group. This is in accordance with our study that reflect the importance of ABG calculations in prediction of ICU admission among blunt chest trauma patients **[22].**

SaO_2 is very important to monitor pulmonary function and can predict trauma related mortality **[29].** In our study, 94 % of ICU admissions was predicted with low SaO_2. In our study, more than 76% of long hospital stay was predicted by SaO_2. Hypoxemia acts as a component of respiratory failure. Our study is in agreement with a study by **Kang *et al.*** **[30],** which reported that tissue hypoxia and lactic acidosis occur because of ventilation and perfusion imbalance as well as gas exchange dysfunction**. Brown *et al.*** **[31]** reported also that patients with poor general condition, hypoxemic/hypercarbia respiratory insufficiency (respiratory rate less than 8 or more than 30 per minute, PO_2 in blood gas less than 55 mmHg, PCO_2 above 55 mmHg, and non-compensated acidosis-alkalosis) need endotracheal intubation guided by ABG results and clinical situation of the patients**.**

In our study, PCO_2 was more sensitive than HCO_3 in prediction of ICU admission. It is in agreement with **Schmoekel *et al.*** **[25]** who reported that PCO_2 values are predictors of respiratory failure, need of intubation and mechanical ventilation. Our study also reported that SaO_2, combined ABG analysis had higher sensitivity in prediction of ICU admission among patients. In our study, HCO_3 level and combined ABG were statistically significant in prediction of lung injury among studied patients with high specificity. A study, done on 67 trauma patients at Critical Care Department of Faculty of Medicine, Cairo University, and included only patients which was admitted to ICU. Patients were divided to 2 groups (survivors and non-survivors). PH was significantly lower in non-survivors, while $PaCO_2$ showed significantly higher values in non-survivors. The study is in agreement with our study that ABG calculations can predict the clinical situation in chest trauma patients **[32].**

CONCLUSION

ABG values and combined ABG values seemed to have a promising role in determination of patients admitted to ward versus others admitted in ICU. Hypoxia, hypercarbia, respiratory acidosis and low P/F ratio usually are present in chest trauma patients admitted to ICU. ABG and combined ABG measurements are strongly reflecting the clinical situation of chest trauma patients. It can predict longer length of hospital stay. ICU admission and longer hospital stay in chest trauma patients can be predicted by SaO_2. PCO_2 is more sensitive than HCO_3 in prediction of ICU admission in chest trauma patients. SaO_2 and combined ABG analysis had higher sensitivity in prediction of ICU admission in chest trauma patients. HCO_3 level and combined ABG seemed to have higher sensitivity and specificity in prediction of lung injury among the studied patients.

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