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A Retrospective Data based comparative study on Electrolytes between Arterial and Venous blood from ICU patients

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ABSTRACT

Background: Electrolyte estimation is an essential component in the management of critically ill ICU patients. Arterial blood gas (ABG) analysers provide rapid bedside electrolyte assessment with shorter turnaround time compared to conventional venous serum electrolyte analysers. However, variations between arterial and venous electrolyte values due to preanalytical and analytical factors may affect their interchangeability.

Aim: To compare electrolyte values between arterial and venous blood samples in ICU patients and to evaluate the correlation between the two methods of estimation.

Materials and Methods: This retrospective comparative study was conducted using data collected from ICU patients. A total of 99 paired arterial and venous blood samples were analysed for sodium, potassium, ionized calcium, and total calcium values. Arterial electrolyte measurements were obtained using ABG analysers, while venous samples were analysed using conventional electrolyte analysers. Statistical analysis was performed using Pearson correlation and paired comparison tests. A p-value of <0.05 was considered statistically significant.

Results: A positive correlation was observed between arterial and venous electrolyte values. Sodium showed a moderate positive correlation ($r = 0.410$, $p < 0.001$), while potassium demonstrated a moderately stronger positive correlation ($r = 0.555$, $p < 0.001$). Ionized calcium showed weak positive correlation ($r = 0.116$, $p = 0.252$), which was not statistically significant. Mean venous sodium (135.39 ± 6.96 mmol/L) was significantly lower than arterial sodium (144.09 ± 10.66 mmol/L). Mean venous potassium (3.64 ± 0.71 mmol/L) was significantly higher than arterial potassium (2.90 ± 0.75 mmol/L). Ionized calcium values differed between arterial(0.624 mmol/L+/- 0.24) and venous samples(0.919 mmol/L+/- 0.17) and the difference was statistically significant.

Conclusion: Arterial and venous electrolyte values showed positive correlation, particularly for sodium, potassiumand Calcium; however, significant differences existed between the two methods of measurement. Ionized calcium demonstrated poor correlation and limited agreement. Although ABG analysers provide rapid bedside electrolyte estimation with reduced turnaround time, arterial and venous electrolyte values cannot be used interchangeably without considering analytical and preanalytical variations. The use of lyophilized heparin-coated syringes may help reduce electrolyte estimation errors in arterial samples.

Keywords*: Electrolytes, ABG and venous blood, ionized calcium in arterial blood and venous blood, Electrolyte in arterial and venous blood, Electrolytes in ICU patients.*

INTRODUCTION

Electrolytes are elements or minerals which when dissolved in water dissociate to carry charge [1]. Sodium, potassium, and ionized calcium are the routinely measured serum electrolytes in daily laboratory practice particularly in treating critically ill patients. Early detection and correction of an electrolyte imbalance is lifesaving for every ICU patient. Inaccurate sodium results may prompt initiation of inappropriate fluid treatment leading to hyponatremia and one of the reversible causes of cardiac arrest is potassium abnormality. This inappropriate values significantly alters Anion gap calculation and thereby misguides the Acid Base status assessment. This is proved in Indian population [2].

Arterial blood is preferred for pH and electrolyte measurement for its stability and short Turn Around time though its puncture cause local pain, haemorrhage, thrombosis, distal embolism. Arterial and venous blood samples differ in their physiological characteristics, in terms of pH, carbon dioxide tension, and oxygenation that the arterial blood typically has a higher pH compared to venous blood due to low carbon dioxide concentration. In circulation, calcium exists in three forms: protein-bound, complexed, and free ionized calcium (iCa). Among these, free ionized calcium (iCa) represents the biologically active fraction and is considered the most accurate indicator of calcium status than total Calcium. Distribution of calcium and other cations (Na, K) between all of these fractions is subject to law of mass action, this equilibrium depends on their concentration, concentration of plasma proteins and low molecular weight ligand anions [3]. In healthy individuals the concentration of ionized free calcium, Sodium and Potassium directly correlates with total concentration because they fairly maintain constant albumin, bicarbonate, phosphate, lactate and citrate. This correlation, falls apart in acute care clinical situations where patients are unable to maintain the normal amount of these metabolites in their blood [4].

In spite of using both arterial and venous samples for electrolytes in clinical practice, the extent of variation in these compartments and their clinical interchangeability remains an area of ongoing investigation. Understanding these differences as crucial, particularly in critical care settings where arterial samples are frequently used for blood gas analysis and electrolytes with less Turn Around Time (TAT) while venous sample is more practical and less invasive, the present study aims to compare the electrolytes levels in arterial and venous blood samples at physiological pH. This study emphasis on identifying systematic and significant differences between the two sampling methods(Arterial and venous) and focuses to evaluate their correlation and agreement.

METHODS & METHODOLOGY:

Study design & setting: This is a retrospective observational and analytical cross sectional study conducted on the data obtained in 24 hr Clinical Biochemistry lab, Stanley medical college & Hospital, Chennai.

Samples: Heparinized whole blood samples 100 in number for ABG analysis received from Emergency department and Intensive care units having the physiological pH of 7.35 to 7.45 were chosen. One out of 100 was rejected due to improper mixing of blood with anticoagulant and fibrin thread was noted. Simultaneously collected 99 venous samples from the same patients for other chemistry analysis in red top tube were chosen. ABG analysis was performed immediately for gas and electrolyte parameters and Venous sample was centrifuged after clot separation time. Serum was separated for electrolytes analysis including ionized calcium in Electrolyte analyzer and total serum calcium in autoanalyser.

Inclusion & exclusion: Care was taken to avoid air bubble during collection and the time of analysis was meticulously followed for ABG analysis. Hemolyzed and lipemic venous samples were rejected. Patients in all age and both genders were included in this study.

Methodology: Electrolytes like Sodium, Potassium, Ionized Calcium were measured in Arterial Blood Gas analyzer using Direct Ion selective Electrode method(ISE) in ROCHE Cobas b221. Electrolytes in venous samples were measured in Electrolyte analyzer ST200 using Direct ISE method. Serum Total Calcium in Chemistry autoanalyser Transasia 640.Both arterial and venous samples were handled under identical laboratory condition to avoid analytical variabilities [6,7].

Statistical Analysis: Done using SPSS. Paired '*t*' tests were used to compare the electrolytes in the two different samples, *p*-value of < 0.05 was considered statistically significant. Arterial and venous blood electrolyte levels were correlated using Pearson's correlation. Concordance Correlation coefficient (CCC) was used to look for agreement between electrolyte values analyzed on an Electrolyte analyzer and ABG analyzer. The results were reported at 95% confidence intervals. The consensus between the electrolyte values analyzed on a venous and arterial sample was also assessed using Bland-Altman

RESULTS

In this study, 99 samples received from Emergency department (ED) and Intensive Care Unit(ICU) data were collected in 24 hrs Clinical Biochemistry Lab. All the samples chosen were with in the physiological pH of 7.35 – 7.45. There were 56 male and 43 female samples showing a slight preponderance to male in ICU admission.

TABLE 1: SEX DISTRIBUTION

sex

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	MALE	56	56.6	56.6	56.6
	FEMALE	43	43.4	43.4	100.0
	Total	99	100.0	100.0	

TABLE 2: CORRELATION OF SODIUM VALUE BETWEEN ARTERIAL AND VENOUS BLOOD

		Na	Na(V)
Na	Pearson Correlation	1	0.410**
	Sig. (2-tailed)		.000
	N	99	99
Na(V)	Pearson Correlation	0.410**	1
	Sig. (2-tailed)	.000	
	N	99	99

**.
Correlation is significant at the 0.01 level (2-tailed).
Statistically there is moderate Correlation between arterial and venous blood Sodium values. Correlation co-efficient Ratio R is 0.410(<1)

TABLE 3: CORRELATION OF POTASSIUM VALUES BETWEEN ARTERIAL AND VENOUS BLOOD

		K	K(V)
K	Pearson Correlation	1	0.555**
	Sig. (2-tailed)		.000
	N	99	99
K(V)	Pearson Correlation	0.555**	1
	Sig. (2-tailed)	.000	
	N	99	99

Statistically there is a moderate correlation in potassium values between arterial and venous blood. Correlation Coefficient Ratio R : 0.555 (<1)

Statistically, there is moderate correlation between the arterial and venous blood potassium level, the Correlation Coefficient Ratio R is 0.555 (<1)

TABLE 4: CORREALTION OF CALCIUM BETWEEN ARTERIAL AND VENOUS BLOOD

		iCa(A)	iCa(V)
iCa(A)	Pearson Correlation	1	0.116
	Sig. (2-tailed)		0.252
	N	99	99
iCa(V)	Pearson Correlation	0.116	1
	Sig. (2-tailed)	0.252	
	N	99	99

Statistically there is poor correlation with arterial and venous blood values of ionized Calcium. R value is 0.116 (<<1)

TABLE 5: COMPARISON TABLE OF ARETERIAL AND VENOUS ELECTROLYTES

	Na(A)	Na(V)	K(A)	K(V)

N	Valid	99	99	99	99
	Missing	0	0	0	0
Mean		144.091	135.394	2.9052	3.6493
Std. Error of Mean		1.0718	.6996	.07573	.07158
Median		145.000	135.000	2.8700	3.5000
Mode		142.7	139.0	2.29	3.10[a]
Std. Deviation		10.6638	6.9608	.75353	.71218
Minimum		110.3	113.0	1.39	2.20
Maximum		167.0	158.0	4.94	6.40

Venous mean Sodium value obtained was **mean:135.3 mmol/L** (max: 158 mmol/L, min:113mmol/L) when compared to arterial mean value of Sodium **144 mmol/L** (max:167 mmol/L min: 110.3mmol/L.) P value: <0.001 Venous mean Potassium obtained was Mean: 3.64 mmol/L(max: 6.4, min:2.2 mmol/L) when comparede to Arterial Potassium of 2.90 mmol/L (max: 4.94, min: 1.39 mmol/L) P value<0.001

TABLE 6: COMPARING THE CALCIUM BETWEEN ARTERIAL AND VENOUS BLOOD

	iCa(A)	iCa(V)	Total Ca
N Valid	99	99	99
Missing	0	0	0
Mean	0.62414	0.9195	8.237
Std. Error of Mean	.024452	.01753	0.1166
Median	.60700	.9000	8.200
Mode	.329[a]	.90	8.2
Std. Deviation	.243291	.17443	1.1597
Minimum	.208	.30	4.4
Maximum	1.207	1.40	11.8

Mean value of Ionized Calcium in venous sample was 0.919 mmol/L (max: 1.4 mmol/L and min: 0.3mmol/L) compared to mean arterial value of 0.624 mmol/L (max: 1.207 mmol/L and min: 0.208 mmol/L) and P value<0.001

Fig 1: Correlation graph of Sodium

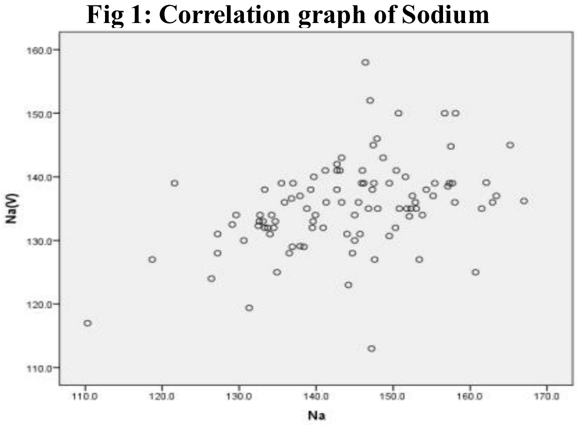


Fig 2: Correlation graph of Potassium

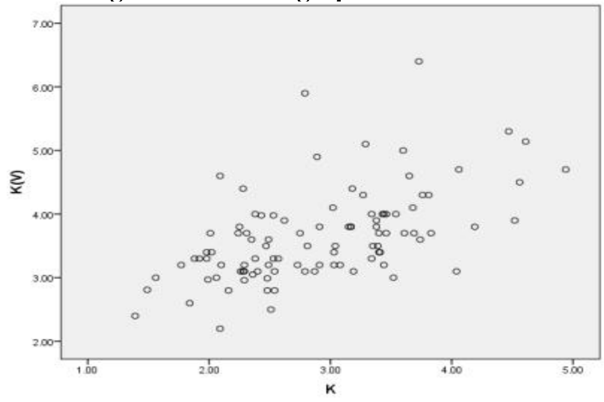
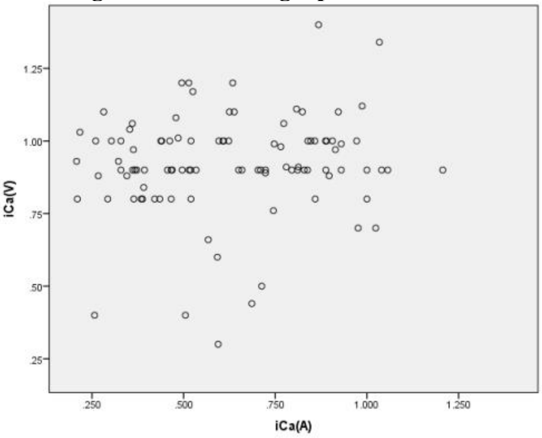


Fig 3: Correlation graph of calcium



DISCUSSION

The incidence of Electrolyte abnormalities is reported around 25% among the ICU patients [13]. Frequent sampling for monitoring Electrolytes in ICU patients increases the hospital laboratory cost of the patient. In actual fact preanalytical sample handling is estimated to account for 75% of the errors in blood gas analysis [22]. The serum separation time around 20 - 30 min delays the Turn Around Time (TAT) which is the major limitation in venous serum sample (Electrolyte analyser)[14]. The arterial samples if collected in containers which are liquid heparinized, then ABG analyzers (BGAs) are more likely to underestimate sodium and potassium levels. The extent of such bias thus will differs among syringe types and it has actually been observed that use of lyophilized heparinized syringes best avoids this kind of underestimation of electrolytes the different heparin volumes in ABG sampling syringes may dilute the whole blood and lower the levels of measured electrolytes in ABG testing [16]

In this study, there is positive correlation between the venous and arterial sample values for Sodium, Potassium and Calcium. The Correlation coefficient ratio (R) is moderate for sodium is 0.411 and moderately stronger for Potassium 0.555 as it is less than 1. R value for Calcium is 0.116 showing a poor correlation between arterial and venous blood.

This study shows a statistically significant difference in measuring venous blood electrolytes and arterial blood electrolytes at physiological pH. Mean Sodium in venous blood (135.39 +/- 6.96)measured in electrolyte analyzer was significantly lesser than arterial Sodium (144.09 +/- 10.66) measured in ABG analyzer. The difference in their mean is statistically significant with P value<0.001. Probable explanation could be multiple factors from pH, protein and lipid concentration, treatment though exact cause not be fixed. Mean Potassium in venous sample (3.64 +/-0.71) is significantly higher than the arterial blood(2.90 +/-0.75). Heparin (polyanion) by binding with the positively charged ions may possibly introduce different negative biases when the levels of electrolytes are measured by BGAs. The most acceptable explanation is the duration between sampling and serum separation time during which the extracellular fluid release of K+ from the red blood cells will elevate potassium levels. Various causes of hemolysis are: prolonged storage at low temperatures or extended time between ICU sampling and Electrolyte analyser analysis, disinfectants with alcohol that are used in ICU, and inappropriate size sampling needles [21]. The magnitude of difference reported in literature is anywhere from 0.1 to 0.7 mmol/L "The United States Clinical Laboratory Improvement Amendment (US CLIA) 2006" accepts a difference of 0.5 mmol/L in measured potassium, and 4 mmol/L in measured sodium, from the gold standard measure of standard calibration solutions. While previous studies have evaluated the interchangeability of arterial and venous biochemical parameters, limited data exist specifically addressing systematic differences in electrolytes in relation to physiological pH in acid–base status particularly in critically ill patients in ICU. Shalini et al. and Budak et al. rule out the possibility of any concordance between venous and arterial blood electrolyte values[10,14]. On the contrary, Nanda et al. mention arterial and venous sodium agree, and Parveen Doddamani et al. report that arterial and venous potassium agree [17,18,19,20]

In this study, there is difference in ionized calcium (iCa) between mean arterial blood (0.624 +/- 0.24mmol/L) and venous sample (0.91+/-0.17 mmol/L) with P value of <0.001 statistically significant. The free ionized calcium which is about 40 – 50% of total calcium concentration 2.05mmol/L (8.23 mg/dL) is achieved (0.82 mmol/L). Some study says polyanion heparin binds with some calcium, if the heparin concentration is kept constant at about 15 IU/mL of blood or lower, the negative effect on ionized calcium [5,15]. This change could be due to change in pH (PCo2) in arterial blood which is comparatively alkaline than venous blood and the release of calcium from bound state. In alkaline pH the calcium bound to protein, anions like phosphates, oxalates, citrate, carbonates are released from them and raise the free ionized calcium. The anaerobic state of body decides the calcium level in ill patients. Satoshi Gando et al study shows similar findings in patients on CPR [8]. R. Revathi et. Al has shown reduced ionized calcium in critically ill patients [9] RN Devaki et al. Arterial electrolytes were found to have lower values than venous sample [10]. Parviz amri et.al study in babol university also has concluded that ABG iCa and venous iCa differs and that iCa in ABG is not acceptable for critical care [11]. Our study supports the concept of using the lyophilised heparin coated syringe which has the least effect in cationic entrapment particularly calcium and altering the arterial values.

CONCLUSION: This study demonstrated a positive correlation between arterial and venous electrolyte values for sodium, potassium, and ionized calcium in critically ill ICU patients. Sodium showed a moderate positive correlation, while potassium demonstrated a moderately stronger correlation between arterial and venous samples. Ionized calcium exhibited poor correlation. These variations may be attributed to differences in sample handling, heparin effects, hemolysis, pH variations, and delay in serum processing. Ionized calcium has poor correlation and statistically significant difference in venous or arterial sample values. However, arterial and venous electrolyte values cannot be used interchangeably without considering the inherent analytical and preanalytical variations. The use of lyophilized heparin-coated syringes is recommended to minimize electrolyte estimation errors in arterial blood samples.

Limitation

This study needs more of sample size and long duration of followup for more details.

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