Correlation between arterial and venous sodium and potassium values in critically ill patients by arterial blood gas and electrolyte analyzer attending tertiary hospital of Nepal

Pramila Bhusal[1], Suresh Prasad Nepal[2]
[1]Consultant, [2]Assoc. Prof., Dept. of General Practice and Emergency Medicine, Bir Hospital, Kathmandu, Nepal

ABSTRACT

Introduction: Electrolytes are elements and compounds that occur naturally in the body and control important physiological function. Electrolyte disorder occurs when the levels of electrolytes in the body are either too high or too low. The causes, severity, treatment, and outcomes can vastly differ depending on the implicated electrolyte imbalances. The objective of this study is to comprehend the correlation between sodium and potassium levels measured in critically ill patients attending a tertiary care hospital of Nepal.

Method: This study was a hospital based prospective observational comparative study conducted in the Department of General Practice and Emergency Medicine, Bir hospital, Kathmandu, from June 2019 to December 2019. After fulfilling inclusion and exclusion criteria a total of 95 patients were included in the study. Data were entered and analyzed in SPSS 20. The findings were presented in figures and tables. Statistical analysis was done using appropriate formula. Mean, standard deviation and correlation coefficient were calculated.

Result: The mean value of arterial sodium was 134.67mmol/L and venous sodium was 135.93mmol/L. The mean value of arterial potassium was 4.0mmol/L and venous potassium was 4.19mmol/L. The correlation coefficient obtained for sodium was 0.703 and for potassium was 0.436. There was positive correlation of arterial sodium and arterial potassium with venous sodium and venous potassium indicating agreement between the parameters.

Conclusion: Arterial sodium and arterial potassium can be used instead of venous sodium and venous potassium levels in management of critically ill patients.

Keywords: Correlation coefficient, critically ill patients, electrolytes, emergency, intensive care unit

CORRESPONDENCE
Dr. Pramila Bhusal
Dept. of General Practice and Emergency Medicine, Bir Hospital, Kathmandu, Nepal
Email: pramilabhusal03@gmail.com

INTRODUCTION

Electrolytes play an important role in continuation of physiological function of human body. Electrolytes are important predictor of mortality and are routinely measured for all critical patients.[1] Among the various electrolyte disturbances, sodium and potassium imbalances are one of the major electrolyte disorders that we encounter in our daily clinical practice.

Electrolytes are measured in the clinical laboratories in both serum and whole blood sample received for arterial blood gas (ABG) analysis. Although the routine practice is to measure electrolytes in serum, but it takes relatively more time due to requirement of separation of serum. Emergency and critical care physicians prefer measurement of electrolytes along with blood gas analysis, which helps them in diagnosis and monitoring of electrolyte imbalance in a short turnaround time. It can play vital role in timely patient management by saving precious minutes.[2]

Since there is no clear consensus on inter exchangeability of results of these analyzers as studies using different devices have reported different results. This study is basically planned to find out whether the electrolytes level measured using ABG analyzer and from the routine laboratory tests are equivalent or not.

Two types of devices that use direct and indirect ion-selective electrode (ISE) methods are used in hospitals for electrolyte measurements: blood gas analyzers (BGA), which use direct ISE technology, and the indirect ISE method, which is often used in a central-laboratory auto analyzer.[3]

Budak, et al., showed that the mean sodium concentration was 138.1 mmol/L (SD10.2 mmol/L) using the ABG and 143.0 mmol/L (SD 10.5) using the Auto analyzer (AA) ($p < 0.001$). The mean potassium level was 3.5 mmol/L (SD 0.9 mmol/L) using the ABG and 3.7 mmol/L (SD 1.0 mmol/L) using the AA ($p < 0.001$). The extent of inter-analyzer agreement was unacceptable for both K^+ and Na^+, with biases of 0.150-0.352 and −0.97-10.05 respectively; the associated correlation coefficients were 0.88 and 0.90. Thus, they concluded that the ABG and Auto analyzer do not yield equivalent Na^+ and K^+ data.[4]

A study conducted in Apollo Hospital, India, where a total of 200 paired samples were analyzed. The mean ABG sodium value was 131.28 (SD 7.33), and the mean AA sodium value was 136.45 (SD 6.50) ($p<0.001$). The mean ABG potassium value was 3.74 (SD 1.92), and the mean AA potassium value was 3.896 (SD 1.848) ($p=0.2679$). Thus, the authors found no significant difference between the potassium values measured by the blood gas machine and the auto-analyzer. However, the difference between the measured sodium was found to be significant. They therefore concluded that trusting the potassium values obtained from the arterial blood gas analysis can make critical decisions.[5]

In one retrospective study conducted on 2014, two hundred and six samples were obtained from intensive care unit patients of Pondicherry Institute of Medical Sciences were included. Out of the 206 samples, 126 were from male patients and 80 were from female patients. The mean value of arterial sodium was 134 and venous sodium was 137. The mean value of arterial potassium was 3.6 and venous potassium was 4.1. The correlation coefficient obtained for sodium was 0.787 and for potassium was 0.701. There was positive correlation of arterial sodium and arterial potassium with venous sodium and venous potassium indicating agreement between the parameters.[6]

METHOD

It is a hospital based prospective, observational comparative study done in Bir Hospital, Mahabouddha, Kathmandu. The duration of study was 6 months. After ethical clearance from Institutional Review Board, National Academy of Medical Sciences (NAMS), data were collected in department of General Practice and Emergency Medicine and ICU from June 2019 to December 2019. Critically ill patients who visited emergency department and ICU, were included in the study, excluding patients who have been treated already for electrolyte imbalance, patient not willing to provide consent, patients below 14 yrs. of age and patient not requiring ABG. Pro-forma was prepared to include demographic data of the participants, laboratory results, and arterial blood gas analysis reports of electrolytes and associated disease conditions.

Validity of the tool was maintained through rigorous literature review. Reliability of the tool was maintained by performing pretest among 5 participants and making essential changes according to the finding of pretest if any required. Simple random sampling method was used and the sample size (n) calculated was 95.

Data was collected via the pro-forma. Blood samples for ABG analysis and routine laboratory studies were obtained simultaneously. The serum samples were obtained by withdrawing 3ml of venous blood in plain vacutainer under aseptic condition. Both the arterial and venous samples were obtained simultaneously with minimal interruption in between. The arterial sample electrolytes were measured from serum by auto-analyzer available in central laboratories of Bir hospital and the sample used for ABG were heparinized whole blood and was sent to ICU (ABL80 Flex BGA) for analysis. ABL 80 Flex Blood gas analyzer uses direct selective electrode whereas auto analyzer uses indirect ion-selective electrode technology. ABL80 blood gas analyzer is portable, easy-to-use for low volume settings.

The reliability and validity of the data was maintained by entering the data in the SPSS software version 20.0. Data analysis was done using Statistical Package for Social Sciences (SPSS) version 20.0. All quantitative parameters were described through descriptive statistics mean, median, mode and standard deviation. P value less than 0.001 was considered as significant. Arterial sodium was correlated with venous sodium and arterial potassium was correlated with venous potassium by Pearson correlation. Scatter plot was employed to represent arterial and venous sodium and potassium.

Declaration

The study started after getting approval of the research protocol from the Institutional Review Board of NAMS and Institutional Review Committee of Bir Hospital. Written informed consent was taken from all the patients enrolled in the study. No forceful participation was induced. Privacy and confidentiality of each case was maintained during and after the study. The patients were ensured that the information given by them will be used only for study purpose and it would not be disclosed anywhere. There was no added cost to the patient. There were no risks or benefits involved for the participants.

RESULT

During the study period, a total of 95 cases were taken as the study group. All participants had undergone series of investigation including baseline investigations and arterial blood gas analysis.

Age and sex distribution

Of the total 95 cases majority of patients maximum i.e (32.63%) were in the age group 61 to 75 years .In the study, patient's age group from 15 to 90years were taken (Fig. 1). The mean age was 59.35 with standard deviation of 17.889.

Of the total 95 cases 52.63% were male and 47.37% were female (Fig 2)

The mean for ABG sodium and serum sodium was 134.67 and 135.93 respectively. (Table 1)

The mean for ABG potassium and serum potassium was 4.00 and 4.19 respectively. (Table 2)

Most common electrolyte imbalance was found to be hyponatremia in general accounting for 46.3% and 37.9 percent out of total participants both in ABG analysis and venous samples respectively and the second common electrolyte imbalance was hypokalemia accounting for 22.1% and 14.7% in arterial and venous samples respectively. (Table 3 and 4)

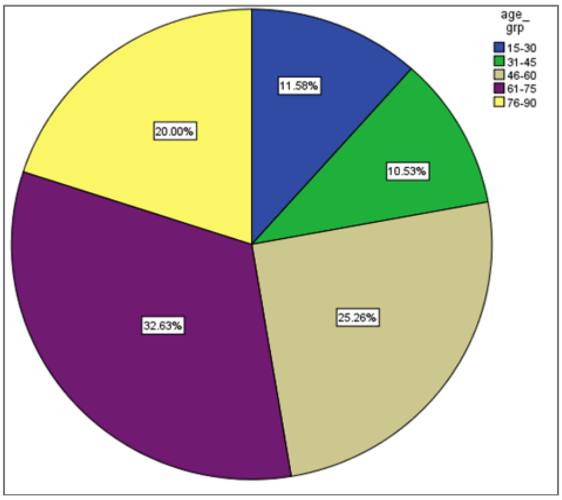

Figure 1. Age distribution

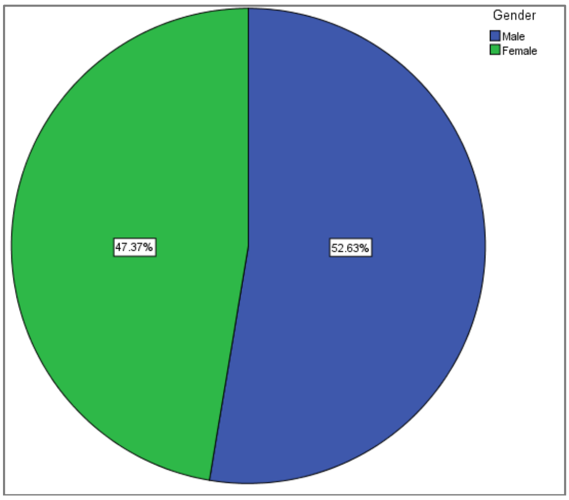

Figure 2. Gender distribution

Table 1. Sodium versus serum sodium

Number of samples	95
Mean for ABG sodium	134.67
Standard deviation for ABG sodium	8.10995
Mean for Serum sodium	135.9337
Standard deviation for Serum sodium	7.84319

Table 2. ABG potassium versus serum potassium

Number of samples	95
Mean for ABG potassium	4.0053
Standard deviation for ABG potassium	0.80391
Mean for Serum potassium	4.1907
Standard deviation for Serum potassium	0.78107

Table 3. Percentage of electrolyte imbalances from arterial sample

Electrolytes	No. of cases	Percentage %
Hypernatremia	5	5.3
Hyponatremia	44	46.3
Hyperkalemia	9	9.5
Hypokalemia	21	22.1

Table 4. Percentage of electrolyte imbalance from venous sample

Electrolytes	No. of cases	Percentage %
Hypernatremia	5	5.3
Hyponatremia	36	37.9
Hyperkalemia	11	11.6
Hypokalemia	14	14.7

Table 5. Mean values of arterial and venous sodium and potassium

Parameter	Mean values	Minimum value	Maximum value
Arterial sodium	134.67	109.2	153
Venous sodium	135.93	110	160
Arterial potassium	4.0053	1.97	6.63
Venous potassium	4.1907	1.20	6.0

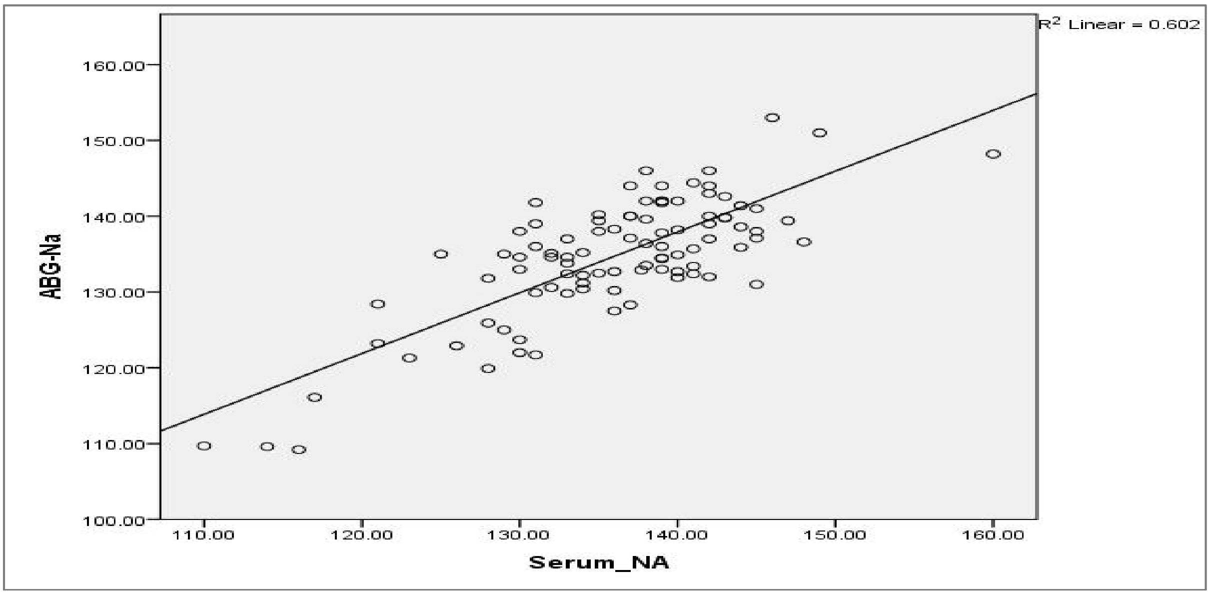

Figure 3. Scattered graph plotted to show correlation between ABG sodium and serum sodium

Table 6. Correlation observed between Serum sodium and ABG sodium

Group		ABG Na	Serum Na
ABG Na	Pearson Correlation	1	.703**
	Sig. (2-tailed)		.000
	N	95	95
Serum Na	Pearson Correlation	.703**	1
	Sig. (2-tailed)	.000	
	N	95	95

**. Correlation is significant at the 0.01 level (2-tailed). (Figure: 3) (Table 6)

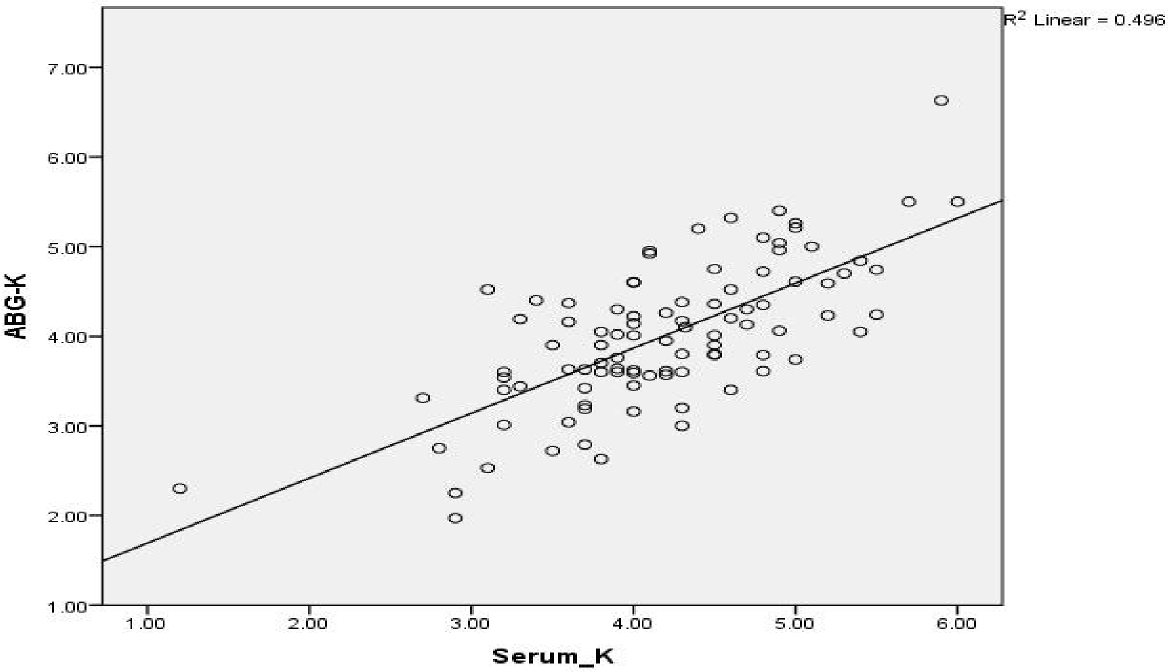

Figure 4. Scattered graph plotted to show correlation between ABG potassium and Serum potassium

Table 7. Correlation observed between serum potassium and ABG potassium

Group		ABG K	Serum K
ABG potassium	Pearson Correlation	1	.436**
	Sig. (2-tailed)		.000
	N	95	95
Serum potassium	Pearson Correlation	.436**	1
	Sig. (2-tailed)	.000	
	N	95	95

**. Correlation is significant at the 0.01 level (2-tailed). (Figure: 4) (Table 7)

DISCUSSION

Critical illness patients require more frequent monitoring of laboratory values especially electrolytes. Point-of-care (POC) analyzers are regularly used by physicians and medical staff in the area of critical care and emergency medicine due to several advantages such as rapid processing times and lower costs.[7] Despite many benefits, there is frequently uncertainty regarding the comparability and validity with central laboratory tests.

In a study conducted in ICU patients of Pondicherry Institute of Medical Sciences, the mean arterial sodium was 134 and the mean venous sodium was 137. The mean arterial potassium was 3.6 and the mean venous potassium was 4.1. The correlation coefficient for sodium was 0.787 and the correlation coefficient for potassium was 0.701. There was positive correlation of arterial sodium and arterial potassium with venous sodium and venous potassium.

In our study, the mean value of arterial sodium was 134.67mmol/L and venous sodium was 135.93mmol/L. The mean value of arterial potassium was 4.0mmol/L and venous potassium was 4.19mmol/L (Table 5).

S Rajavi, et al., observed higher levels of sodium and potassium in serum when compared to sodium and potassium in arterial blood. These lower arterial values could be explained by dilution effect of heparin since arterial samples are collected in heparinized containers.[8]

Similar to the above studies, slightly higher values in venous samples results when compared to the arterial sodium and potassium values may be explained by the dilution effect of heparin in case of arterial samples.

Jain, et al., found no significant difference between the potassium values measured by blood gas machine and auto-analyzer, however; the difference between the measured sodium was significant. According to Jain A et al., the cause for lower values of electrolytes in arterial blood is because of binding of heparin to electrolytes.[5]

Abdullah, et al., concluded that though the correlation between serum and arterial electrolytes was significant however, related to time it was weakly negative. They concluded that critical decisions can be made by considering values obtained through both ABG and Serum levels of the electrolytes.[9]

The use of different syringes or tubes containing the anticoagulant in sample preparations may be responsible for the pre analytical bias of the measured electrolytes in the ABG device.[10] Dilution of the plasma volume of the sample with the use of conventional syringes washed with liquid heparin may cause the actual value of the BGA electrolytes to be lower. In addition, heparin itself binds positively charged ions and lowers the value of the electrolytes measured.[11]

According to Chacko B et al., the reasons for such differences between the arterial and serum electrolytes could be attributed to difference in sample, whole blood and serum, difference in the type of electrode used and difference in the use of calibrators.[12]

In a study conducted in Emergency department of Uludag University, which included 996 patients with electrolyte imbalance, sodium disorder was found to be the most common electrolyte imbalance accounting for 65% of the cases among which 60 % had hyponatremia.[13]

Like the above study, most common electrolyte imbalance was found to be hyponatremia in general accounting for 46.3% and 37.9 percent out of total participants both in ABG analysis and venous samples respectively. And the second common electrolyte imbalance was hypokalemia accounting for 22.1% and 14.7% in arterial and venous samples respectively in my study.

Shilpi Awasthi, et al., observed that there was a strong correlation between the arterial sodium and potassium and venous sodium and potassium which were like the findings of the present study.[14]

In this study, the minimal sodium level in ABG and serum was found to be 109.2 and 110 respectively. And the minimum level of potassium in ABG and serum was 1.97 and 1.2 respectively. The maximum value of sodium in ABG and Serum was 153 and 160 respectively and of potassium in ABG and serum was 6.63 and 6.0 respectively.

Mestric Z et al., observed that electrolytes measured in whole blood by point of care analyser were comparable to electrolytes measured in plasma or venous serum samples, as similar to our study. The mean sodium level measured by ABG was 136.1±6.3 mmol/L and 137.8±5.4 mmol/L for AA (p=0.001). The Pearson's correlation coefficient was 0.561 (p<0.001) showing a positive correlation between the values obtained.[15]

In our study, the mean value of arterial sodium was 134.67mmol/L and venous sodium was 135.93mmol/L. The mean value of arterial potassium was 4.0mmol/L and venous potassium was 4.19mmol/L. The correlation coefficient obtained for sodium was 0.703 and for potassium was 0.436. The correlation between the two methods of analysis arterial and venous blood analysis results were positive with p value of less than 0.001 indicating agreement between the parameters (Table 6 and 7; Fig. 3 and 4).

Thus, in this study a positive correlation was seen as seen in many of the above-mentioned studies suggesting the interchangeability of the sodium and potassium levels from ABG and autoanalyzer in the management of critically ill patients in Emergency and Intensive care units. This study is a single centered study of short duration so further studies are needed.

CONCLUSION

Sodium and potassium analyzed in ABG analyzer is comparable to the sodium and potassium levels measured in electrolyte analyzer. Arterial sodium and arterial potassium can be used instead of venous sodium and venous potassium levels in management of critically ill patients.

In view of the positive correlation between the values of sodium and potassium in both the ABG and Serum samples and the time difference, being insignificant, we conclude that critical decisions can be made for clinical decision-making in trusting the values obtained through both ABG and Serum levels of the electrolytes.

Further research is needed to establish their accuracy in other parameters.

Acknowledgement
We would like to thank all the individuals who directly or indirectly helped in completion of this study.

Conflict of interest
None

REFERENCES

1. Madhavi, Nikhila G. Arterial blood gas analyser electrolytes versus serum electrolytes: a comparative study. Int J Life Sci Pharma Res. 2018;8(2):37-51. | Full Text | Weblink |
2. Gupta S, Gupta AK, Singh K, Verma M. Are sodium and potassium results on arterial blood gas analyzer equivalent to those on electrolyte analyzer? Indian J Crit Care Med. 2016;20(4):233-7. | DOI |
3. Ustundağ Y, Huysal K, Ozgunay ŞE, Turkoğlu AR. Interchangeability of sodium and potassium result values of arterial blood gas with laboratory analyzer: narrative review. Indian J Crit Care Med. 2019;23(1):35-42. | DOI |
4. Budak YU, Huysal K, Polat M. Use of a blood gas analyzer and a laboratory autoanalyzer in routine practice to measure electrolytes in intensive care unit patients. BMC Anesthesiol. 2012;12:17. | DOI |
5. Jain A, Subhan I, Joshi M. Comparison of the point-of-care blood gas analyzer versus the laboratory auto-analyzer for the measurement of electrolytes. Int J Emerg Med. 2009;2(2):117-20. | DOI |
6. Nanda SK, Ray L, Dinakaran A. Agreement of arterial sodium and arterial potassium levels with venous sodium and venous potassium in patients admitted to intensive care unit. J Clin Diagn Res. 2015;9(2):BC28-30. | DOI |
7. Price CP. Medical and economic outcomes of point of care testing. Clin Chem Lab Med. 2002;40(3):246-51. | DOI |
8. Razavi S, Jafari A, Zaker H, Sadeghi A. Plasma and serum electrolyte levels correlation in the pediatric ICU. Tanaffos. 2010;9(4):34-38. | Full Text |
9. Alanazi A, Al Obaidi NY, Enezi FA, AlMutairi MK, Aljerian N. Alsultan OA, et al. Correlation between the measurements of serum and arterial blood gas (ABG) electrolytes in patients admitted to the intensive care unit at King Abdul-Aziz Medical City, Riyadh, Saudi Arabia. Am J Clin Med Res. 2015;3(3):55-9. | Full Text |
10. Chhapola V, Kumar S, Goyal P. Is liquid heparin comparable to dry balanced heparin for blood gas sampling in intensive care unit? Indian J Crit Care Med. 2014;18((1):):14-20. | DOI |
11. Van Berkel M, Scharnhorst V. Electrolyte-balanced heparin in blood gas syringes can introduce a significant bias in the measurement of positively charged electrolytes. Clin Chem Lab Med. 2011;49((2):):249-52 | DOI |
12. Chacko B, Peter JV, Patole S, Fleming JJ, Selvakumar R. Electrolytes assessed by point-of-care testing - are the values comparable with results obtained from the central laboratory? Indian J Crit Care Med. 2011;15(1):24-9. | DOI |
13. Singal BM, Hedges JR, Succop PA. Efficacy of the stat serum electrolyte panel in the management of older emergency patients. Med Decis Making. 1992;12(1):52-9. | DOI |
14. Awasthi S, Rani R, Malviya D. Peripheral venous blood gas analysis: an alternative to arterial blood gas analysis for initial assessment and resuscitation in emergency and intensive care unit patients. Anesth Essays Res. 2013;7(3):355-8. | DOI |
15. Flegar Mestric Z, Perkov. S. Comparability of point-of-care whole-blood electrolyte and substrate testing using a Stat Profile Critical Care Xpress analyser and standard laboratory methods. Clinical Chemistry Lab Medicine. 2006; 44:898-903. | DOI |