EDITORIAL

ABG Analyzer for Electrolyte Measurement in ICU Patients: To Do or Not to Do

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Keywords: ABG electrolytes, Autoanalyzer, ICU, Laboratory research, Potassium, Sodium, Turnaround time.
Indian Journal of Critical Care Medicine (2024): 10.5005/jp-journals-10071-24722

Introduction

Electrolyte abnormalities are considered common in intensive care unit (ICU) patients, the incidence rate reported is nearly 25%.[1] There is enough evidence in literature, regarding levels of serum sodium and potassium, being mortality predictors in ICU patients.[2] Intuitively, inaccurate sodium results may prompt initiation of inappropriate fluid administration which can result in hypervolemia, highlighting need for accuracy of estimation. While serum potassium concentrations, demands shortest time possible to get back results, as abnormal concentrations are one of the common reversible cause of cardiac arrest in critically ill patients. Accurate estimation of electrolytes also has additional importance in diagnosing etiology of various diseases through calculating anion gap. These examples underlines the importance to quickly fetch accurate data, so as to optimize therapeutics and minimize response time.

Since electrolyte levels of ICU patients are monitored frequently, sending samples to central lab increases the hospital laboratory costs of the patients. In cases of ICU personnel processing, ABG samples for electrolytes as well with the ABG machine within the ICU, both labor as well as reagent costs are decreased in comparison to autoanalyzer (AA) at central laboratory.[3]

The delayed turnaround, which minimally is around 20–30 minutes due to requirement of separation of serum, is major limitation of AA.[4]

On the other hand, point of care ABG analyzers when used to measure arterial blood electrolytes can make results available within 5 minute, thus decreasing the turnaround time. The major ascendency of ICU blood gas analyzers comes from the fact that they need no centrifugation.[5]

In routine hospital practice, central laboratories mostly set serum electrolytes turnaround time at around 90 minutes, considering centrifugation time, test processes, and overall sample volumes. Although the AA results are concluded to be more accurate and definitive by ICU clinicians, the relatively long TAT of autoanalyzer's remains a limitation in the management of ICU patients.[2] Mostly for this reason, critical care physicians often prefer point-of care testing (POCT) along with blood gas analysis, for measurement of electrolytes. The AA and ABG measured electrolyte results are used in inter exchangeable manner, often in a belief that as they are equivalent.

The AAs used in central hospital laboratories mostly employ indirect assay, requiring pre-analytic dilution. While ABG analyzers/POCT equipment utilizes the direct ISE method, in which a complete undiluted blood sample comes in contact with electrode surface.

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How to cite this article: Tyagi N. ABG Analyzer for Electrolyte Measurement in ICU Patients: To Do or Not to Do. Indian J Crit Care Med 2024;28(5):416–418.

Source of support: Nil

Conflict of interest: None

Both electrolyte assay methods are direct as well as indirect, employ ion-sensing electrodes (ISEs).[6]

In this issue of Indian Journal of Critical Care Medicine, the authors attempted to investigate if electrolytes in venous blood are equivalent to the levels in arterial blood.[7] In this retrospective study, electrolytes report of 200 patients from whom both arterial and venous blood samples were dispatched to hospital clinical biochemistry lab on the same day and at the same time for analysis were analyzed. They concluded that when concordance correlation coefficient and Bland-Altman plot analysis was made there was no agreement between electrolytes analyzed on serum in an autoanalyzer with that of arterial blood gas analyzer. Thus, further confirming the notion that the electrolytes measured in serum derived from venous blood sample by conventional AA cannot be replaced by values of arterial blood sample analyzed on a ABG analyzer. These results are in contrast to a similar size cross-sectional study that showed "arterial sodium and potassium measured by ABG can be used instead of AA measured venous sodium and potassium levels in critically ill patient's management."

The Dichotomy or Conflict in Results

Despite reduced POCT turnaround time, there are accuracy and reliability concerns POCT devices can't be overstated. The fact that, whole blood vs plasma levels of Na^+ and K^+ have been shown to be identical, further confounds any attempts to explain the conflicting results just on this basis.[8]

A number of studies that measured the accuracy of electrolyte values obtained by ABG analyzers concluded that results obtained from these POCT analyzers significantly differed for sodium and potassium concentrations from AAs, which affected values of strong ion difference as wells calculated anion gaps.[5,9] On the other hand, other authors in their study have observed acceptable accuracy between AA vs point of care ABG analyzer's electrolytes.[10]

Before trying to make sense of any of the study results one should take note that "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.

Difference Due to Analyzers or Arterial vs Venous Blood

The bias found in comparison of AA vs ABG can be ascribed to that the fact that the two different methods (indirect vs direct ISE) are employed, regarding the electrolyte measurements. A study which reviewed 3 months retrospective clinical laboratory data, observed that hypoproteinemia when present, was associated mainly with sodium level overestimation, when using the indirect ISE method. In addition, when comparing the two methods, 50% of samples with protein level 100 gm/L were still in contravention to USCLIA 88 rule. Thus, it is fair to contemplate that both hypo or hyperproteinemia can lead to variance in results.

Given that critically ill patients are known to suffer with high prevalence of hypoproteinemia, as per this study, sodium levels from AAs get poorly evaluated, and hence potentially can lead to erroneous clinical management. The study results may also lead to an erroneous notion that for such critically ill patients, ABG results are less likely to be altered by serum protein levels.[4]

Another prospective study done to clear up debate regarding arterial vs venous electrolyte concentrations, compared whether the Na^+ and K^+ levels in the "arterial samples" measured through ABG and AA stand equivalent. Consistent with prior research, for sodium levels, difference (although not statistically different) was found between the two methods, while regarding the mean potassium levels, there was statistically significant difference. The authors attributed the findings primarily to the fact that ABA and AA uses different sample types, i.e. whole blood vs serum.[11]

In contrast one study comparing arterial blood ABG vs venous blood AA measurements, found smaller biases of electrolytes, except for potassium. The fact that this was a meaningful and practical real-world comparison, the significantly reduced electrolytes that was reported further substitutes that, such measurements by ABG analyzers need to be interpreted with caution.[12]

Recently some authors have also reported the fact that, arterial samples if collected in containers which are liquid heparinized, then ABG analyzers (BGAs) are more likely to underestimate sodium and potassium levels. Heparin by binding with the positively charged ions may possibly introduce different negative biases when the levels of electrolytes are measured by BGAs.[13]

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.[14]

ABG Sodium Level Estimation

In a frequently cited study, it was revealed that results for the plasma Na^2 and Cl^{-1} levels, significantly differed with AA and ABG. Moreover, these anomalies altered the calculated anion gap to significant extents, which has a potential to lead to an entirely different acid–base status assesment.[15] Similar findings have been confirmed when studied in Indian population as well.[16]

As pointed earlier, a recent study reconfirmed significant difference between these two methods regarding reported sodium levels. Despite the mean sodium level differences between AA and ABG stayed very small, the Bland-Altman's 95% limits of agreement for sodium were very wide, thus not clinically acceptable. It also revealed that even in normonatremia group (which represented 76% of the total patients), a significant difference was found between these two analyzing methods.[17] So to summarize, even if mean difference reported in sodium results has been around 1.7 mmoL/L, the limits of agreement were as wide as –2.9–6.4 mmoL/L. For normonatremic range, mean difference being 3.4 mmoL/L, which increased to 7.4 mmol/L in the 120–135 mmoL/L group, reaching highest to 12.8 mmol/L in the <120 mmoL/L sodium group. Considering all these study data at this point, making clinical decisions based on ABG results for sodium, seems to be unreliable.[18,19]

AA vs ABG Potassium Level

Almost all studies so far have pointed to the fact that a statistically significant difference remains between the AA vs ABG measured mean potassium levels.[17]

The magnitude of difference reported in literature is anywhere from 0.1 to 0.7 mmol/L. Few reasons may potentially address this difference between these two analyzing methods. Considering in either serum or else whole blood, 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 AA analysis, disinfectants with alcohol that are used in ICU, and inappropriate size sampling needles.[20]

Few researchers attempted to derive correction factor for ABG potassium vs AA Potassium, hoping to use the results interchangeably. But most concluded, this correction factor being highly variable, thus needs to be determined ideally, individually for each hospital. Therefore, it is important that every center conducts its own determination with regard to concordance between AA and BGAs potassium levels.[18]

Under these circumstances, it is not an exaggeration to conclude that, though probably urgent clinical corrections can be made through the BGAs determined potassium levels, a simultaneous as well as follow-up samples should be sent for central lab AA confirmations.[21]

Conclusion

In conclusion, it needs to be emphasized that blood gas analyzers tend to present lower results when compared with chemistry analyzers, and these findings suggest that the results from these two different kinds of analyzers cannot be used interchangeably. Moreover, removing adequate amount of the discarded volume is essential for avoiding dilution with flush fluid when sampling from a catheter. Moreover, the different heparin volumes in ABG sampling syringes may dilute the whole blood and lower the levels of measured electrolytes in ABG testing.[14]

For this reason, pre-heparinized dry and balanced syringes are recommended for ABG sampling particularly for simultaneous estimation of electrolytes.

Take-home Message

It needs to be pointed that the results obtained are specific to the AA or ABG analyzer used. That is why intensivists need to be aware of the importance of determining the concordance between the electrolyte values obtained by AA and ABG, for each hospital

individually. The usage of a correction factor thus calculated may minimize the differences between the analyzing instruments. While one cannot advice the use of sodium results interchangeably because they differ significantly between AA and ABG. Conversely, it is possible to make vital decisions by the potassium levels obtained from the ABG machines, while awaiting confirmation via AA results.

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