Reliability of venous blood gas sodium, potassium and creatinine

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ABSTRACT

OBJECTIVE: To determine the level of correlation between sodium, potassium and creatinine readings between point-of-care venous blood gas (VBG) and laboratory biochemistry measurements (LBM).

METHODS: Data was obtained from three Monash Health (one of the largest health networks in metropolitan Melbourne) emergency departments. 16,527 VBGs were matched with LBM for sodium, 16,437 for potassium and 8,597 for creatinine. Pearson correlation and further subgroup analyses were carried out to explore if acid-base imbalance affected sodium, potassium or creatinine reliability in VBG.

RESULTS: The range of VBG values showed more variation in comparison to LBM. There was good correlation ($r>0.8$, $p<0.001$) between measured values with the exception of potassium in acidaemia, however, there was consistent and statistically significant difference in measured values.

CONCLUSIONS: The small mean differences across all three parameters observed although statistically significant are unlikely to be clinically significant. With minor calibrations, this would be an easily corrected problem. As such, we recommend that sodium, potassium and creatinine measurements can be used interchangeably between the VBG and LBM, with the exception of potassium levels in acidaemia. Potassium levels in acidaemia should be used with caution due to lower correlation.

Due to the nature of acute presentations in emergency departments (ED), point-of-care venous blood gas is widely used and becoming increasingly popular.[1]

Quick turnover of patients or necessity to institute time-critical management in critically unwell patients such as diabetic ketoacidosis (DKA) or electrolyte imbalance regardless of cause and for ease of re-evaluation[2] are two main reasons of this popularity. A number of parameters are measured on a venous blood gas (VBG).

Multiple researches since 2001 have supported the use of VBGs secondary to being less invasive with sufficient agreement and correlation when acid base status, electrolytes or even haemoglobin are of concern. However, it's not a substitute for arterial blood gases (ABG) when assessing ventilation and oxygenation. VBG applicability is yet to be ascertained in shock states or mixed acid-base disturbances.[3]

Furthermore, VBGs have not been validated with laboratory methods (LBM) using a large sample size. If validated, swifter investigations, referrals and diagnoses can be reached with resulting cost-effectiveness. For instance, semi-urgent contrast CT scans that are reliant on renal function could be performed without delay with a VBG creatinine reading.

Some previous publications have compared electrolyte measurements in VBG and LBM, but none of them included creatinine in their studies,[4–10] and there hasn't been any clear agreement when comparing these parameters. In addition, the largest published study cited less than 1,000 samples.[10] Utilising a larger sample size will reduce the chance of random error and may give light to a more definitive answer as to the correlation between the two measurement methods. Using the power of a larger sample size, this paper will explore the potential of using VBG readings interchangeably with the LBM. In particular, we

will explore the correlation of electrolytes sodium and potassium, as well as creatinine.

Methods

Data was obtained from Monash Health emergency department presentations. Monash Health is one of the major health networks in Melbourne, with an annual ED census of approximately 200,000 presentations across three hospitals: Monash Medical Centre (tertiary), Dandenong and Casey (district) hospitals. This study was approved by Monash Health and the Monash University Human Research and Ethics Committee.

21,770 individualised VBG readings were matched against LBM samples, received by the laboratory within five minutes (ensuring the same samples). These samples were matched by a hospital identification number, and duplicate readings from the same patient (eg, across a few days) were excluded. These readings were obtained for the period when records for both VBGs and LBM were accessible electronically. 16,527 records were matched for sodium, 16,437 for potassium and 8,597 for creatinine through patient identification numbers and registered sample time. Error readings were excluded, resulting in 16,514 samples for sodium, 16,509 samples for potassium and 8,597 samples for creatinine (Figure 1).

Statistical analysis was carried out using Microsoft Office Excel 2011, and further subgroup analysis including Pearson correlation coefficient was carried out to explore the effect of acid-base disturbances on the reliability of the sodium and potassium readings.

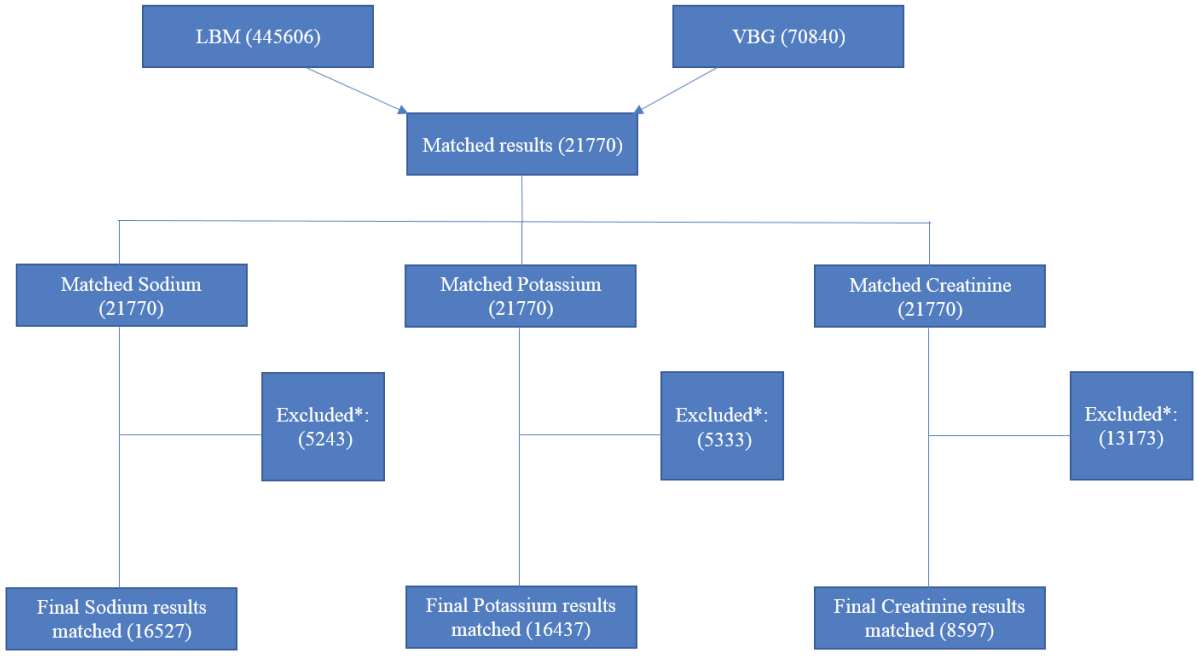
Pearson correlation coefficient (PCC) also referred to as **Pearson's *r***, is a measure of the linear correlation between two variables (the covariance of the two variables divided by the product of their standard deviations. It has a value between +1 and −1, where 1 is total positive linear correlation, 0 is no linear correlation and −1 is total negative linear correlation.

Results

Sodium and potassium

Both acidaemia and alkalaemia were recorded, with the mean pH (7.37) within the human physiological range (7.35–7.45). For both electrolytes, the VBG returned a wider range of results than the LBM, however, mean and standard deviations (SD) of the values were similar (Table 1). Mean differences for both electrolytes across all pH states were significant ($p<0.001$). Sodium levels across all pH states were marginally over-estimated by the VBG. Despite the over-estimation, there was high correlation ($r=0.84–0.85$) between the VBG and LBM.

Figure 1: Study design diagram, including excluded results due to error.



*Readings excluded were due to "error" readings on instrument.

Table 1: VBG parameters.

Value	Range	Unit
pH	7.35–7.45	
PvCO2	35–35	mmHg
Bicarbonate ($HCO3^-$)	20–24	mmol/L
Base Excess (BE)	-3 to +3	mmol/L
Sodium (Na^+)	135–145	mmol/L
Potassium (K^+)	3.5–5	mmol/L
Chloride (Cl^-)	95–107	mmol/L
Blood sugar level (BSL)	4–12	mmol/L
Lactate (Lact)	less than 2	mmol/L
Creatinine	60–110	umol/L
Haemoglobin	130–180	g/L

Potassium levels were marginally underestimated across all pH states. Apart from a medium strength correlation (r=0.58) for potassium in acidaemia, results were highly correlated (r=0.85–0.89) in the other pH states and overall (Table 2).

Creatinine

With regards to creatinine, we noticed a slight increased variation comparing VBG with LBM (SD 123 vs 118) despite similar minimum and maximum values (Table 3).

A significant mean difference of 2.55 was observed with a high correlation between the samples (r=0.99) (Table 4).

All mean differences recorded were statistically significant (p<0.001), with good correlation (r>0.8). However, in the subgroup analyses, potassium in an acidaemic sample demonstrated a lower correlation comparing VBG and LBM.

Discussion

The LBM utilises indirect whereas the VBG measures direct ion-sensing electrodes to determine serum electrolytes. The differing methods give a good case for further investigation to understand their comparability and interchangeable utility in clinical practice.

In direct method (VBG), the electrolytes are measured on an undiluted sample with a turn over time of between 2–3 minutes,

Table 2: Potassium and sodium values in VBG and LBM.

	Analysis	Minimum	Maximum	Mean	SD
	pH (VBG)	6.36	7.74	7.37	0.082
Na (n:16,514)	**VBG**	120	166	138	4.07
	LBM	121	154	137	3.71
K (n:16,509)	**VBG**	2.5	7.6	4.043	0.565
	LBM	2.9	7.5	4.169	0.546

Table 3: Analysis of differences between sodium and potassium values by metabolic state in VBG and LBM.

	Comparison	Mean difference	SD	95% CI	R	p
Na	Overall	1.1	2.21	1.07 ; 1.14	0.84	<0.001
	Aklalaemia	0.777	2.17	0.67 ; 0.89	0.85	<0.001
	Acidaemia	1.26	2.42	1.20 ; 1.33	0.84	<0.001
	Normal pH	1.07	2.11	1.03 ; 1.11	0.84	<0.001
K	Overall	-0.127	0.256	-0.131 ; -0.123	0.89	<0.001
	Aklalaemia	-0.146	0.258	-0.159 ; -0.133	0.85	<0.001
	Acidaemia	-0.0617	0.821	-0.0843 ; -0.0391	0.58	<0.001
	Normal pH	-0.128	0.237	-0.132 ; -0.123	0.88	<0.001

Table 4: Range of creatinine values in VBG and LBM.

Creatinine (µmol/L)	Minimum (µmol/L)	Maximum (µmol/L)	Mean (µmol/L)	SD
VBG	10.5	1,655	110	123
LBM	9	1,585	108	118

Table 5: Analysis of differences of creatinine values recorded on VBG and LBM.

	MD	SD	95% CI	R	p
Creatinine comparison	2.55	18.0	2.17 ; 2.94	0.99	<0.001

whereas in indirect method (LBM), the plasma sample is diluted then analysed, with the process time being at least 30 minutes, as such to be able to reliably utilise the VBG results in assessment and management of a critically unwell patient, VBG would be optimal.

Sodium and potassium haemeostasis occur in slightly different but related ways. Sodium is closely related to fluid balance through baroreceptors, aldosterone and ADH,[11] and potassium is mainly intracellular and largely maintained by renal mechanisms as part of the body's buffering system.[12] As a result, changes in pH might affect their concentrations, hence the rationale for studying electrolyte changes generally as well as various pH states. Apart from potassium in the acidaemia, the rest of the correlation coefficients (r) by pH states and in general, were demonstrating high correlation. The fact that potassium is generally underestimated by VBG and acidosis can maintain hyperkalaemia, the VBG might be more sensitive to higher potassium levels, resulting in a lowered mean difference. It is interesting that even though the mean difference is the least out of all four pH states, the correlation should be only moderate (r=0.58).

From clinical perspective and its potential life-threatening nature, hyperkalaemia is crucial to be recognised imminently either clinically or biochemically, therefore a further specific subgroup analysis was performed. Reviewing all the LMB with potassium level of more than 5mmol/L revealed just one discrepancy where an LBM reading of 6mmol/L was reported as 5.4mmol/L on the VBG samples with no major clinical significance, confirming a strong correlation again as demonstrated.

Correlation of the hyperkalaemia in VBG with ECG findings was out of the scope of this study. However, we believe any abnormal ECG findings suggestive of hyperkalaemia in a clinically unstable patient requires urgent intervention regardless. Consequently, we believe that the VBG is clinically useful in the acute setting to identify hyperkalaemia.

According to Menchine et al, VBG electrolyte results were 100% specific and 97.8% sensitive in DKA.[4] The authors, with a sample of 342 patients, demonstrated that correlation coefficients of 0.9 for sodium. This is in agreement with our finding that sodium levels highly correlates between VBG and LBM. The study also showed good correlations between other parameters like chloride (r=0.73), bicarbonate (r=0.94) and the anion gap (r=0.81), which is beyond the scope of our study but are additional preliminary findings in support of the utility of the VBG especially in an emergency situation like DKA.

Multiple other studies with limited samples, purported that biochemistry and glucose results were comparable but had relatively few samples.[8] In one study, 59 paired samples from the paediatric intensive care unit were underestimated and statistically significant.[5] King and Campbell[7] found good agreement between VBG and formal UECs however concluded that the results should be used with caution because of wide limits of agreement. In a Turkish study, the authors found an underestimation of potassium levels with the VBG.[9] Finally, another study found a significant difference in potassium levels in the normal pH range; the conclusion was that potassium levels are not reliable on the VBG.[10]

A potential limitation to the study is lack of ability to control for the sampling of the blood gases. As this was a retrospective study and as large a sample size as possible was desired, there was no control for site or method of collection including tourniquet placement. This is possibly relevant in that tissue metabolism and ischemia varies with these variable changes and can contribute to differences in blood gas readings.[13–14] Secondly, we excluded extreme results which were obviously in error (refer to methods), but there might have been some less extreme readings that were retained for comparison which were not clinically correlated and would have been discarded or the test re-run. Finally, our results might vary with others depending on calibration of machine and possibly brand and model.

Conclusions

Limited researches with conflicting findings are available on this topic and studies thus far have had relatively small sample sizes. Our study demonstrated good positive correlation between venous blood gas and laboratory biochemistry measurements of sodium, potassium and creatinine, with the exception of potassium in the acidaemia. Minor adjustments in VBG assay could be made to potentially reduce the mean difference, however, the small mean differences might not significantly affect clinical decision making in management, especially with a slight difference of 2.55 for creatinine. Based on our study, sodium, potassium and creatinine measurements can be used interchangeably between the techniques with mild correction, and in acidaemia potassium levels should be used with caution in lieu of a lower observed correlation.

Take home message

Overall there is a good clinical positive correlation between venous blood gas and laboratory biochemistry measurements of sodium, potassium and creatinine.

Competing interests:
Nil.

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