Comparison among bicarbonate and base excess values as obtained from NCCLS standard C12-A equations and from equations suggested by other authors

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ABSTRACT

This article reports a compared evaluation of NCCLS standard C12-A equations for bicarbonate and base excess (BEb) withother algorithms suggested by other authors and used by different emogas analyzers.

RIASSUNTO

L'articolo riporta una valutazione comparata delle equazioni NCCLS standard C 12-A per bicarbonato ed eccesso di base in rapporto ad altri algoritmi suggeriti da diversi autori ed utilizzati da alcuni emogasanalizzatori.

INTRODUCTION

In the evaluation of acid-base status, most parameters are measured (pO2,pCO2,pH) other are derived.

Sometime, difficulties for clinical interpretation arise from the large number of calculated parameters and from the variability of the reported values, depending on the algorithm in use.

Aim of this work is to make a comparison among the values of bicarbonate (HCO3) and of base excess (BEb), calculated using different algorithms, with the results obtained using the reference equations approved in the document NCCLS standard C12-A (1):

all the algorithms used in our comparison are listed in tab. 1 and 2.

The two parameters that mainly contribute in generating differences among the algorithms are the negative logarithm of the apparent equilibrium constant of bicarbonate, pK, and the solubility constant of CO2 in plasma.

As already pointed out (6), those values have been obtained as the results of repeated approximations and elaborations of experimental data .

Although they frequently differ only by the second or third decimal figure, those differences may have a great

Table 1
Algorithms for HCO3 and BEb considered for the comparison

algorithm			ref.
1	$HCO3^{-} = 10\text{^}(pH+0.037*pCO2-6.105)$	NCCLS	(1)
2	$HCO3^{-} = 10(pH+10(pCO2-7.604))$	Nova STAT 1	(2)
3	$HCO3^{-}= 0.0304*pCO2 *10\text{^}(pH-6.1)$	AVL OMNI	(3)
4	$HCO3^{-} = 0.031*pCO2 *10\text{^}(pH-6.1)$	Ciba Corning 278	(4)
5	$*HCO3^{-} = 0,2*pCO2 *10\text{^}(pH-pK)$	Radiometer ABL 500	(5)

*where pK=6.125-log (1+10^(pH-8,7))

Table 2
Algorithms for HCO3 and BEb considered for the comparison

algorithm			ref.
6	BEb=(1-0.014*Hb)+(HCO3-24,8)+(1.43*Hb+7.7)*(pH-7.4)	NCCLS and AVL OMNI	(1)
7	BEb=(1-0.014*Hb)+(HCO3-24)+(1.43*Hb+7.7)*(pH-7.4)	NOVA STAT 1	(1)
8	BEb=(1-0.014*Hb)+(HCO3-24,8)+(1.63*Hb+9.5)*(pH-7.4)	Ciba Corning 278	(4)

Hb = hemoglobin concentration il g/dl
pCO2= partial pressure of CO2 in mm/Hg
HCO3-= bicarbonate concentration in mmol/L
pK= apparent equilibrium constant of bicarbonate

impact on the final result, since they enter in the exponential calculation.

Method

For the tests 245 data of pH, pO2 and pCO2 have been obtained from real whole blood samples measured on the following instruments: Blood Gas AVL Omni (AVL -List, Austria) Ciba Corning 278 (Ciba Corning Diagnostic Corp. -Medfield, MA) Radiometer ABL 500 (Radiometer - Copenhagen , Denmark) NOVA Stat 1 (Nova Biomedical-Waltam Mass, USA)

Each sample has been tested in single: because not of importance for our purpose, we did not discriminate among results obtained from blood sampled in syringe, capillary or tube nor among samples collected in different anticoagulants.

All the samples used for our evaluations were either arterial blood, drawn and immediately analyzed, or venous whole blood tonometered with gas at different percentage of O2 and CO2 for including in our observation also the limits of the physiological range.

The total hemoglobin concentration of the tested samples ranged from 5 to 21 g/dl. The values obtained from the instrumental report have been transferred to a worksheet of Excel 5.0 for the statistical elaboration

In tab. 3 are reported the minimum and maximum value for each measured parameter.

RESULTS

Actual bicarbonate

Equations 1-5 reported above are referred to the so-called actual bicarbonate, not normalized at standard pH and pCO2 conditions.

It must be noted that, because the value of HCO3 is taken into account in the computation of the anion gap, it is important that the bicarbonate concentration does not make misleading the interpretation of the other parameters in which this value is entered.

The value of pK more commonly considered varies between 6.0 and 6.105, while the solubility of the carbonic anhydride for the different algorithms included in the range between 0.0304 and 0.0310 mmol/L/mmHg. In equation 5, CO2 solubility (0.23) is expressed in mmol/L/Kpa and is equal to 0.0306 mmol/L/mmHg

The equations of the regression lines obtained in tab. 4.

Table 3
Minimum and maximum limit of the parameters considered in the evaluation

Parameter	min	max
pH	6.952	7.746
pO2 mmHg	16.1	209
pCO2 mmHg	23.6	125.8
THb g/dL	5	21

As it can be seen from tab 4, different slopes are obtained for the different algorithms that enter in the computation: the linear regression lines, show that only AVL Omni has a negligible slope, due to the minimal differences between the value of pK and the solubility constant of CO2 versus the equation NCCLS standard C12-A.

For all correlation, the regression line crosses the axis at 0 offset is except for the algorithm of Radiometer ABL 500. Here the differences are rather spread and not directly correlated with the value of HCO3 of the reference: for this algorithm the value of pK is computed for each single sample, depending on the pH measured.

Assuming that:

1) the normal range for measured HCO3 in an arterial sample is between 22 and 26 mmol/L

2) the min and max values detectable in a whole blood sample are 10 and 60 mmol/L respectively

we have considered the differences observed at those values, including also the value of 30 that is just in the middle of the extent of HCO3 concentration in blood.

The results of that elaboration are summarized in tab. 5.

Base excess

The base excess is a calculated parameter that gives a good indication about whether the deviation is due to a metabolic or respiratory imbalance, taking into account the value of pCO2.

As for bicarbonate, BEb is reported as an actual value, that is, the measured value are entered in the computation without any correction, neither for temperature nor pH.

We have compared the values obtained from each equation with the algorithm NCCLS standard C12-A: the concentration of HCO3 that is considered for each computation is the one derived from the corresponding instrument or method.

The correlation between the algorithm of NCCLS standard C12-A and the biases referred to the compared algorithms is often polynomial, this indicates how the weight of the variables is different for the different ranges considered.

The plots obtained and the corresponding equations are reported in fig. 1-3

As previously proceeded for bicarbonate, we have evaluated the differences between the value obtained with the reference equation and the algorithms of comparison,

Table 4
Equation of the linear regressions for correlation of the algorithms of table 1 with NCCLS standard C-12 A

	slope	intercept	r^2
Corning	0.021	0	1
AVL	0.002	0	1
NOVA	0.03	0	1
Radiometer	0.008	0.15	0.002

Table 5
Biases of 5 different equation for HCO3 determination vs NCCLS standard C12-A: deviation for the normal range values (22-26 mmol/L) and for the extreme values found in pathologic samples (10 -60 mmol/L). for each algorithm, the pooled SD of the differences are also reported

	HCO3 mmol/L					
	normal		pathologic			
	22	26	10	30	60	SD pooled differences
Bias Corning	0.5	0.5	0.3	0.9	1.8	0.11
Bias AVL	0.044	0.052	0.02	0.06	0.12	0.009
Bias NOVA	0.7	0.8	0.3	0.9	1.8	0.166
Bias Radiometer	0.5/0.5	-0.5/0.5	-0.5/0.5	-0.5/0.5	-0.5/0.5	0.3

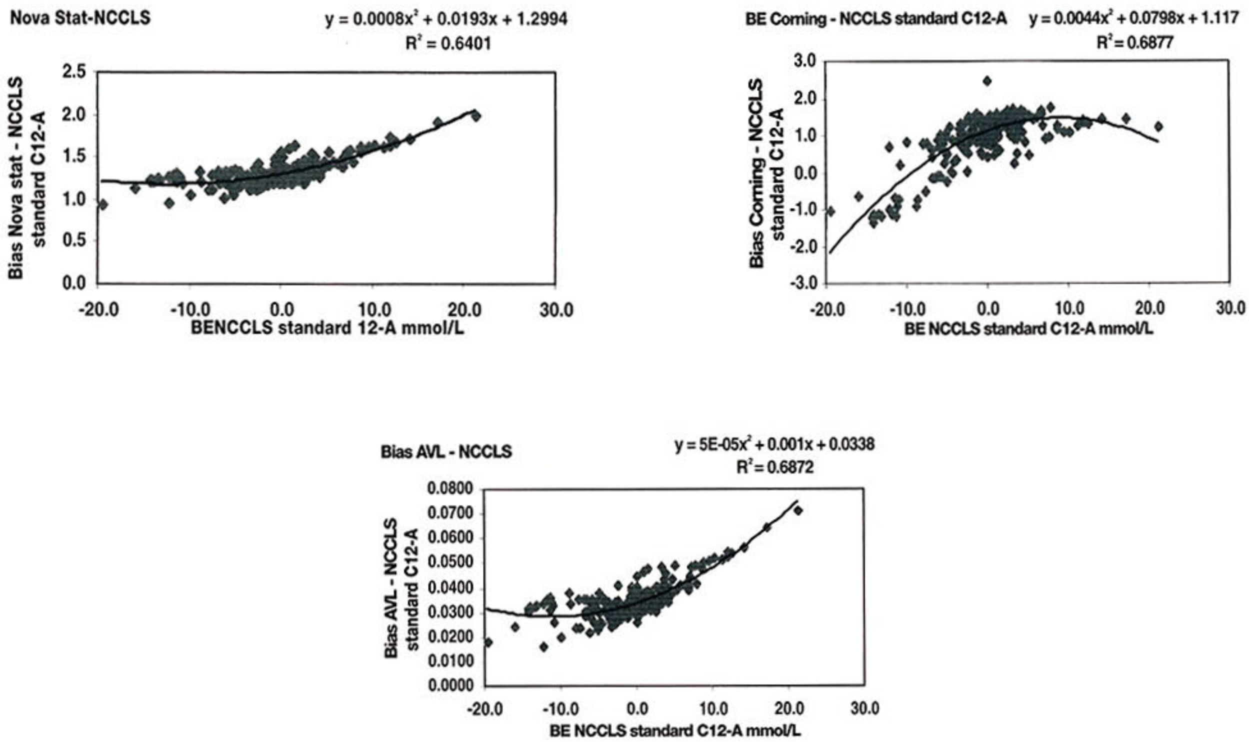

Figure 1-3
Correlation plots of BEb values obtained with the algorithm of NCCLS standard C12-A and the biases observed using the algorithms considered for the comparison

considering both the normal range (-2 and 2 mmol/L) and the extreme values (-20 and +20 mmol/L) observed with real samples, besides the 0 value.

Tab. 4 shows the results of the elaboration besides the pooled SD of the biases.

DISCUSSION

At this time in clinical laboratories different instruments are in use that apply different equations, set up with continuos verifications and corrections, in conclusion with a high degree of approximation and contingency.

Even if some of the differences observed in the comparison are not so meaningful per se, a problem is met in case of monitoring a trend of a patient considering the same parameter obtained with two different instruments: theoretically, it would be necessary to know the originating algorithm in each case: indeed the procedure seems to be quite inapplicable, and, let alone, this could not be realistically proposed.

It would be desirable that all the manufacturer of emogas analyzers would reach a common definition, adopted for all instruments: the general application of NCCLS standard C12-A equation would give much uniform reports joined with a proper definition of the used constants.

Table 6
Biases of 3 different equations for BEb determination vs NCCLS standard C12-A : deviation for the normal range values (-2,2 mmol/L) and for the extreme values found in pathologic samples (-20 20 mmol/L). for each algorithm, the pooled SD of the differences are also reported

	BEb mmol/l					
	normal	range	patho logical	range		
NCCLS standard C12-A	-2	2	-20	0	20	SD pooled differences
Bias NOVA	1.264	1.3412	1.2334	1.2994	2.0054	0.137
Bias AVL	0.035	0.036	0.0138	0.0338	0.0538	0.661
Bias Corning	0.9398	1.2766	-2.239	1.117	0.953	0.007

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