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Mathematical Equivalent of Metabolic Alkalosis Part of the Goldberg Acid–Base Map

To the Editor:—Metabolic alkalemia is the most common acid–base disturbance among patients in the hospital.[1] Because the disorder is associated with high mortality and morbidity, its prompt diagnosis and treatment is feasible.

The expected physiologic compensation for a primary increase in serum bicarbonate concentration ($[HCO_3^-]$), *i.e.*, metabolic alkalosis, is hypoventilation that increases partial pressure of arterial carbon dioxide (Pa_{CO_2}; hypercapnia). This compensatory process returns the elevated blood pH back to normal, however, metabolic alkalosis is less predictably compensated than other simple acid–base disorders.[2]

In 1973, Goldberg *et al.*,[3] based on the Henderson Hasselbalch equation, developed an acid–base map, describing the expected levels of the arterial blood pH, $[HCO_3^-]$, and P_{CO_2} in different acid–base disturbances. For bedside application, however, a simple equation that describes the metabolic alkalosis portion of the Goldberg map would facilitate rapid interpretation of whether an individual set of arterial blood gases was consistent with a compensated metabolic alkalosis.

To develop an equation that describes the expected compensatory increase in Pa_{CO_2} in response to a primary increase in serum $[HCO_3^-]$, using a digitizer (CalComp 9500; full size), the minimum and maximum expected Pa_{CO_2} values associated with serum $[HCO_3^-]$, ranging from 27 mEq/l to 51 mEq/l were identified. Because compensatory hypoventilation rarely results in a Pa_{CO_2} exceeding 55 mmHg,[2] values more than 55 mmHg were assumed to be equal to 55 mmHg.

Using the principle of least squares, it was found that the area outlined by two parallel lines containing these data points was defined by the equation ($r = 0.97$, $P < 0.0001$) expected $Pa_{CO_2} = 0.54[HCO_3^-] + 27.84 \pm 4.17$.

This equation is mathematically equivalent to the graphical presentation of the metabolic alkalosis portion of the Goldberg map. Because of the wide confidence interval, for more convenient use at the bedside, the equation can be simplified as follows:

$$\text{expected } Pa_{CO_2} = 0.5[HCO_3^-] + 28 \pm 4$$

The equation was tested against 33 arterial blood gas data sets obtained from patients with pyloric stenosis who were admitted to our wards for postprandial vomiting for several days (table 1). The blood gas data of the first 25 patients, according to the previous equation, are compatible with a compensated metabolic alkalosis. The remaining patients (patients 26–33), however, had degrees of respiratory acidosis also. This respiratory acidosis is of no clinical importance in patients 26–28 and was expected in patients 29–33 who were old and had degrees of chronic obstructive pulmonary diseases.

Farrokh Habibzadeh, M.D.
Mahboobeh Yadollahie, M.D.
General Practitioner
National Iran Oil Company Outpatient Polyclinics
Shiraz, Iran
habibzaf@sums.ac.ir

Table 1. Test of the Equation Against 33 Patients with Postprandial Vomiting of Several Days

			P_{CO_2} (mmHg)	
Number	*p*H	$[HCO_3^-]$ (mEq/l)	Observed	Expected Range
1	7.50	37.6	49.8	42.8–50.8
2	7.55	41.3	49.2	44.7–52.7
3	7.49	31.6	43.1	39.8–47.8
4	7.43	30.3	47.1	39.2–47.2
5	7.42	29.1	46.2	38.5–46.5
6	7.50	34.3	45.4	41.2–49.2
7	7.47	34.0	47.7	41.0–49.0
8	7.48	34.2	46.9	41.1–49.1
9	7.47	33.5	48.0	40.8–48.8
10	7.44	29.0	44.0	38.5–46.5
11	7.46	29.7	42.9	38.8–46.8
12	7.54	37.4	45.4	42.7–50.7
13	7.52	38.9	48.6	43.5–51.5
14	7.50	31.9	42.1	40.0–48.0
15	7.50	34.2	45.2	41.1–49.1
16	7.51	37.0	48.0	42.5–50.5
17	7.50	35.8	47.5	41.9–49.9
18	7.55	37.5	44.0	42.8–50.8
19	7.53	38.4	47.6	43.2–51.2
20	7.46	30.8	44.2	39.4–47.4
21	7.50	32.1	42.1	40.0–48.0
22	7.47	29.9	42.1	39.0–47.0
23	7.49	32.3	44.2	40.2–48.2
24	7.47	32.6	46.5	40.3–48.3
25	7.51	36.3	46.7	42.2–50.2
26	7.40	28.1	46.5	38.0–46.0
27	7.51	41.4	53.5	44.7–52.7
28	7.49	39.4	52.8	43.7–51.7
29	7.48	38.0	53.1	43.0–51.0
30	7.41	31.0	50.0	39.5–47.5
31	7.44	33.8	51.4	40.9–48.9
32	7.47	38.5	54.9	43.3–51.3
33	7.45	37.1	55.6	42.5–50.5

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