TABLE 66-1 PREDICTION OF COMPENSATORY RESPONSES ON SIMPLE ACID-BASE DISTURBANCES AND PATTERN OF CHANGES

Disorder	Prediction of Compensation	Range of Values		
		pH	HCO_3^-	$Paco_2$
Metabolic acidosis	$Paco_2 = (1.5 \times HCO_3^-) + 8 \pm 2$ *or* $Paco_2$ will ↓ 1.25 mmHg per mmol/L ↓ in $[HCO_3^-]$ *or* $Paco_2 = [HCO_3^-] + 15$	Low	Low	Low
Metabolic alkalosis	$Paco_2$ will ↑ 0.75 mmHg per mmol/L ↑ in $[HCO_3^-]$ *or* $Paco_2$ will ↑ 6 mmHg per 10 mmol/L ↑ in $[HCO_3^-]$ *or* $Paco_2 = [HCO_3^-] + 15$	High	High	High
Respiratory alkalosis		High	Low	Low
Acute	$[HCO_3^-]$ will ↓ 0.2 mmol/L per mmHg ↓ in $Paco_2$			
Chronic	$[HCO_3^-]$ will ↓ 0.4 mmol/L per mmHg ↓ in $Paco_2$			
Respiratory acidosis		Low	High	High
Acute	$[HCO_3^-]$ will ↑ 0.1 mmol/L per mmHg ↑ in $Paco_2$			
Chronic	$[HCO_3^-]$ will ↑ 0.4 mmol/L per mmHg ↑ in $Paco_2$			

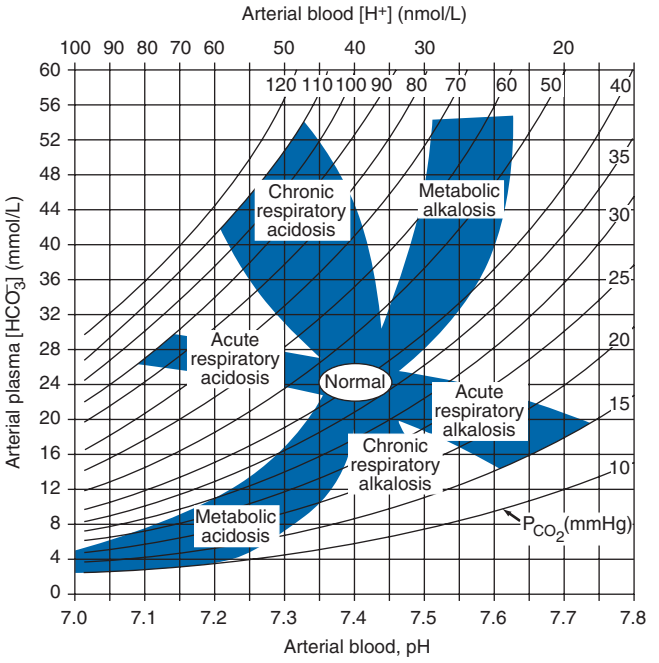

FIGURE 66-1 Acid-base nomogram. Shown are the 90% confidence limits (range of values) of the normal respiratory and metabolic compensations for primary acid-base disturbances. *(From TD DuBose Jr: Acid-base disorders, in Brenner and Rector's The Kidney, 8th ed, BM Brenner [ed]. Philadelphia, Saunders, 2008, pp 505–546, with permission.)*

the ratio of $[HCO_3^-]$ to $Paco_2$, and thus pH, toward, but not to, normal. The degree of respiratory compensation expected in a simple form of metabolic acidosis can be predicted from the relationship: $Paco_2 = (1.5 \times [HCO_3^-]) + 8 \pm 2$. Thus, a patient with metabolic acidosis and $[HCO_3^-]$ of 12 mmol/L would be expected to have a $Paco_2$ between 24 and 28 mmHg. Values for $Paco_2$ <24 or >28 mmHg define a mixed disturbance (metabolic acidosis and respiratory alkalosis or metabolic alkalosis and respiratory acidosis, respectively). Compensatory responses for primary metabolic disorders move the $Paco_2$ in the same direction as the change in $[HCO_3^-]$, whereas, conversely, compensation for primary respiratory disorders moves the $[HCO_3^-]$ in the same direction as the primary change in $Paco_2$ (Table 66-1). Therefore, changes in $Paco_2$ and $[HCO_3^-]$ in **opposite directions** (i.e., $Paco_2$ or $[HCO_3^-]$ is increased, whereas the other value is decreased) indicate a **mixed disturbance**. Another way to judge the appropriateness of the response in $[HCO_3^-]$ or $Paco_2$ is to use an acid-base nomogram (Fig. 66-1). While the shaded areas of the nomogram show the 95% confidence limits for normal compensation in simple disturbances, finding acid-base values within the shaded area does not necessarily rule out a mixed disturbance. Imposition of one disorder over another may result in values lying within the area of a third. Thus, the nomogram, while convenient, is not a substitute for the equations in Table 66-1.

MIXED ACID-BASE DISORDERS

Mixed acid-base disorders—defined as independently coexisting disorders, not merely compensatory responses—are often seen in patients in critical care units and can lead to dangerous extremes of pH (Table 66-2). A patient with diabetic ketoacidosis (metabolic acidosis) may develop an independent respiratory problem (e.g.,

TABLE 66-2 EXAMPLES OF MIXED ACID-BASE DISORDERS

Mixed Metabolic and Respiratory

Metabolic acidosis—respiratory alkalosis

Key: High- or normal-AG metabolic acidosis; prevailing $Paco_2$ *below* predicted value (Table 66-1)

Example: Na^+, 140; K^+, 4.0; Cl^-, 106; HCO_3^-, 14; AG, 20; $Paco_2$, 24; pH, 7.39 (lactic acidosis, sepsis in ICU)

Metabolic acidosis—respiratory acidosis

Key: High- or normal-AG metabolic acidosis; prevailing $Paco_2$ *above* predicted value (Table 66-1)

Example: Na^+, 140; K^+, 4.0; Cl^-, 102; HCO_3^-, 18; AG, 20; $Paco_2$, 38; pH, 7.30 (severe pneumonia, pulmonary edema)

Metabolic alkalosis—respiratory alkalosis

Key: $Paco_2$ does not increase as predicted; pH higher than expected

Example: Na^+, 140; K^+, 4.0; Cl^-, 91; HCO_3^-, 33; AG, 16; $Paco_2$, 38; pH, 7.55 (liver disease and diuretics)

Metabolic alkalosis—respiratory acidosis

Key: $Paco_2$ higher than predicted; pH normal

Example: Na^+, 140; K^+, 3.5; Cl^-, 88; HCO_3^-, 42; AG, 10; $Paco_2$, 67; pH, 7.42 (COPD on diuretics)

Mixed Metabolic Disorders

Metabolic acidosis—metabolic alkalosis

Key: Only detectable with high-AG acidosis; $\Delta AG >> \Delta HCO_3^-$

Example: Na^+, 140; K^+, 3.0; Cl^-, 95; HCO_3^-, 25; AG, 20; $Paco_2$, 40; pH, 7.42 (uremia with vomiting)

Metabolic acidosis—metabolic acidosis

Key: Mixed high-AG—normal-AG acidosis; ΔHCO_3^- accounted for by combined change in ΔAG and ΔCl^-

Example: Na^+, 135; K^+, 3.0; Cl^-, 110; HCO_3^-, 10; AG, 15; $Paco_2$, 25; pH, 7.20 (diarrhea and lactic acidosis, toluene toxicity, treatment of diabetic ketoacidosis)

Abbreviations: AG, anion gap; COPD, chronic obstructive pulmonary disease; ICU, intensive care unit.