Supplemental Text Box 2

Hyperventilation

Most of the CO2 produced by body metabolism is eliminated via the lungs—by the act of breathing—thereby keeping levels of arterial CO2 (PaCO2) within homeostatic limits on a minute-by-minute basis. In healthy individuals breathing normally, a PaCO2 of 35–40 mm Hg ensures a blood pH of 7.35–7.45. Hyperventilation, breathing in excess of metabolic demands, washes out CO2 stores and can cause respiratory alkalosis (high pH) within minutes. Even small changes in CO2—and thereby pH—can cause significant shifts in homeostasis. In chronic hyperventilation, in which body stores and arterial levels of CO2 are already low, hypocapnia can be maintained by occasional deeper breaths, and blood pH is kept in the homeostatic range by renal excretion of bicarbonate (the body’s alkaline-buffering system).

Increased ventilation in the face of perceived threat—danger in the environment, extreme anger, pain, or other intense emotions—is part of the body’s preparation for action. With the onset of hyperventilation, blood flow to the brain, heart, gut, and skin decreases (vasoconstriction), and blood flow to large skeletal muscles (arms and legs) increases (vasodilation). Cerebral vasoconstriction—and concurrent EEG slowing—underpins a broad range of functional neurological symptoms, including dizziness, disorientation, visual phenomena (blurred vision, clouded vision, tunnel vision, flashing lights, or complete blackout), impaired mental performance, lack of memory for the event, or loss of consciousness (syncope). Vasoconstriction and reactivity of coronary blood vessels can result in atypical chest pain. Detectable changes on ECG (changes in height of the R wave, T wave inversion, and ST depression) are well documented.

Changes in blood flow appear to be mediated by sympathetic efferents in interaction with the local effects of low PCO2 and high pH. In essence, systems involved in immediate self-protective action are activated, whereas redundant systems are shut down. The mild alkalosis functions to offset any surge of CO2 and the lactic acid production associated with strenuous muscular action.

Alongside, and as a consequence of, changes in PaCO2 and pH, hyperventilation causes various physiological changes. There is a shift in the oxygen dissociation curve (the Bohr effect): when blood pH is high (alkalosis), oxygen molecules bind more tightly to erythrocyte hemoglobin, resulting in lower oxygen release to tissues. Hyperventilation also induces decreases in blood phosphate, total calcium, ionized magnesium, and potassium. Not surprisingly, hyperventilation-induced physiological changes can affect the functioning of body systems in many ways, although the pattern of symptoms and their severity vary considerably among individuals.

REFERENCES


