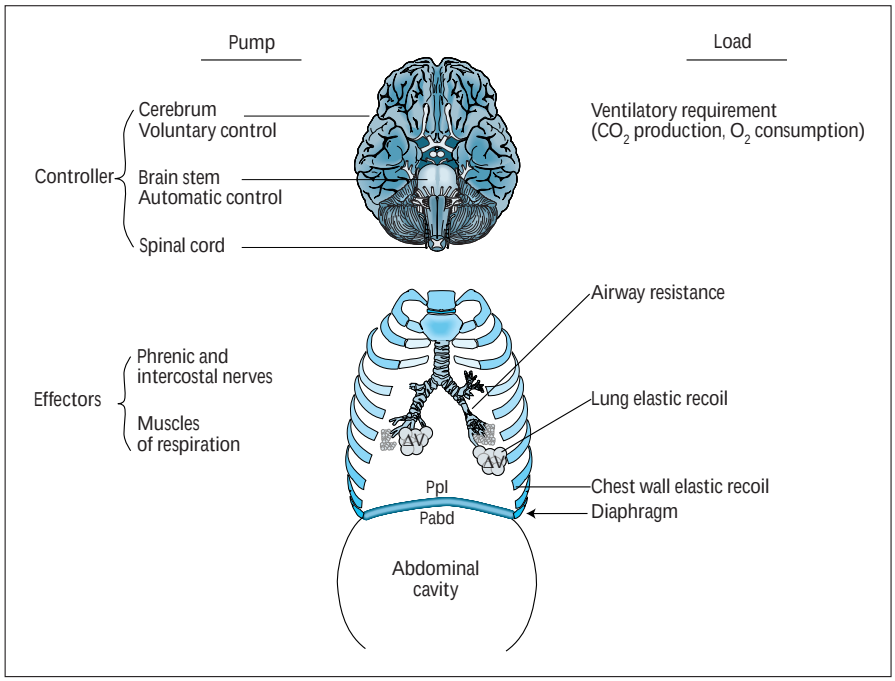

FIGURE 6-4

Main components of the ventilatory system. The ventilatory system is responsible for maintaining the arterial carbon dioxide tension ($PaCO_2$) within normal limits by adjusting minute ventilation ($\dot{V}$) to match the rate of carbon dioxide production. The main elements of ventilation are the respiratory pump, which generates a pressure gradient responsible for air flow, and the loads that oppose such action. The machinery of the respiratory pump includes the cerebrum, brain stem, spinal cord, phrenic and intercostal nerves, and the muscles of respiration. Inspiratory muscle contraction lowers pleural pressure (Ppl) thereby inflating the lungs (ΔV). The diaphragm, the most important inspiratory muscle, moves downward as a piston at the floor of the thorax, raising abdominal pressure (Pabd). The inspiratory decrease in Ppl by the respiratory pump must be sufficient to counterbalance the opposing effect of the combined loads, including the airway flow resistance, and the elastic recoil of the lungs and chest wall. The ventilatory requirement influences the load by altering the frequency and depth of the ventilatory cycle. The strength of the respiratory pump is evaluated by the pressure generated (ΔP = Ppl - Pabd).

DETERMINANTS AND CAUSES OF CARBON DIOXIDE RETENTION

Respiratory Pump

- Depressed Central Drive
  - Acute
    - General anesthesia
    - Sedative overdose
    - Head trauma
    - Cerebrovascular accident
    - Central sleep apnea
    - Cerebral edema
    - Brain tumor
    - Encephalitis
    - Brainstem lesion
  - Chronic
    - Sedative overdose
    - Methadone or heroin addiction
    - Sleep disordered breathing
    - Brain tumor
    - Bulbar poliomyelitis
    - Hypothyroidism
- Abnormal Neuromuscular Transmission
  - Acute
    - High spinal cord injury
    - Guillain-Barré syndrome
    - Status epilepticus
    - Botulism
    - Tetanus
    - Crisis in myasthenia gravis
    - Hypokalemic myopathy
    - Familial periodic paralysis
    - Drugs or toxic agents *eg*, curare, succinylcholine, aminoglycosides, organophosphorus
  - Chronic
    - Poliomyelitis
    - Multiple sclerosis
    - Muscular dystrophy
    - Amyotrophic lateral sclerosis
    - Diaphragmatic paralysis
    - Myopathic disease *eg*, polymyositis
- Muscle Dysfunction
  - Acute
    - Fatigue
    - Hyperkalemia
    - Hypokalemia
    - Hypoperfusion state
    - Hypoxemia
    - Malnutrition
  - Chronic
    - Myopathic disease *eg*, polymyositis

Load

- Increased Ventilatory Demand
  - High carbohydrate diet
  - Sorbent-regenerative hemodialysis
  - Pulmonary thromboembolism
  - Fat, air pulmonary embolism
  - Sepsis
  - Hypovolemia
- Augmented Airway Flow Resistance
  - Acute
    - Upper airway obstruction
      - Coma-induced hypopharyngeal obstruction
      - Aspiration of foreign body or vomitus
      - Laryngospasm
      - Angioedema
      - Obstructive sleep apnea
      - Inadequate laryngeal intubation
      - Laryngeal obstruction after intubation
    - Lower airway obstruction
      - Generalized bronchospasm
      - Airway edema and secretions
      - Severe episode of spasmodic asthma
      - Bronchiolitis of infants and adults
  - Chronic
    - Upper airway obstruction
      - Tonsillar and peritonsillar hypertrophy
      - Paralysis of vocal cords
      - Tumor of the cords or larynx
      - Airway stenosis after prolonged intubation
      - Thymoma, aortic aneurysm
    - Lower airway obstruction
      - Airway scarring
      - Chronic obstructive lung disease *eg*, bronchitis, bronchiolitis, bronchiectasis, emphysema
- Lung Stiffness
  - Acute
    - Severe bilateral pneumonia or bronchopneumonia
    - Acute respiratory distress syndrome
    - Severe pulmonary edema
    - Atelectasis
  - Chronic
    - Severe chronic pneumonitis
    - Diffuse infiltrative disease *eg*, alveolar proteinosis
    - Interstitial fibrosis
- Chest Wall Stiffness
  - Acute
    - Rib fractures with flail chest
    - Pneumothorax
    - Hemothorax
    - Abdominal distention
    - Ascites
    - Peritoneal dialysis
  - Chronic
    - Kyphoscoliosis, spinal arthritis
    - Obesity
    - Fibrothorax
    - Hydrothorax
    - Chest wall tumor

FIGURE 6-5

Determinants and causes of carbon dioxide retention. When the respiratory pump is unable to balance the opposing load, respiratory acidosis develops. Decreases in respiratory pump strength, increases in load, or a combination of the two, can result in carbon dioxide retention. Respiratory pump failure can occur because of depressed central drive, abnormal neuromuscular transmission, or respiratory muscle dysfunction. A higher load can be caused by increased ventilatory demand, augmented airway flow resistance, and stiffness of the lungs or chest wall. In most cases, causes of the various determinants of carbon dioxide retention, and thus respiratory acidosis, are categorized into acute and chronic subgroups, taking into consideration their usual mode of onset and duration [2].

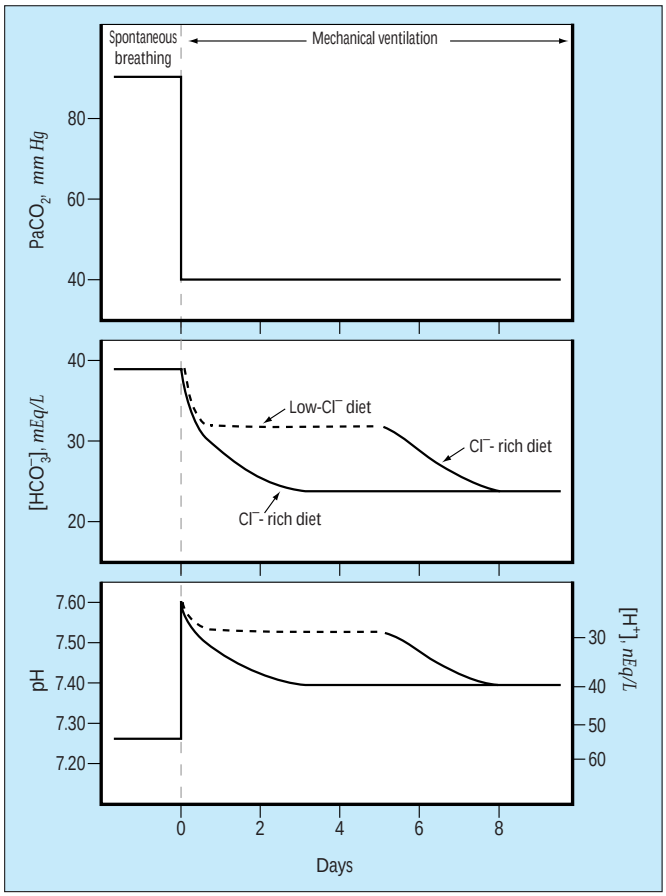

FIGURE 6-6

Posthypercapnic metabolic alkalosis. Development of posthypercapnic metabolic alkalosis is shown after abrupt normalization of the arterial carbon dioxide tension ($PaCO_2$) by way of mechanical ventilation in a 70-year-old man with respiratory decompensation who has chronic obstructive pulmonary disease and chronic hypercapnia. The acute decrease in plasma bicarbonate concentration ($[HCO_3^-]$) over the first few minutes after the decrease in $PaCO_2$ originates from alkaline titration of the nonbicarbonate buffers of the body. When a diet rich in chloride (Cl^-) is provided, the excess bicarbonate is excreted by the kidneys over the next 2 to 3 days, and acid-base equilibrium is normalized. In contrast, a low-chloride diet sustains the hyperbicarbonatemia and perpetuates the posthypercapnic metabolic alkalosis. Abrupt correction of severe hypercapnia by way of mechanical ventilation generally is not recommended. Rather, gradual return toward the patient's baseline $PaCO_2$ level should be pursued [1,2]. $[H^+]$—hydrogen ion concentration.

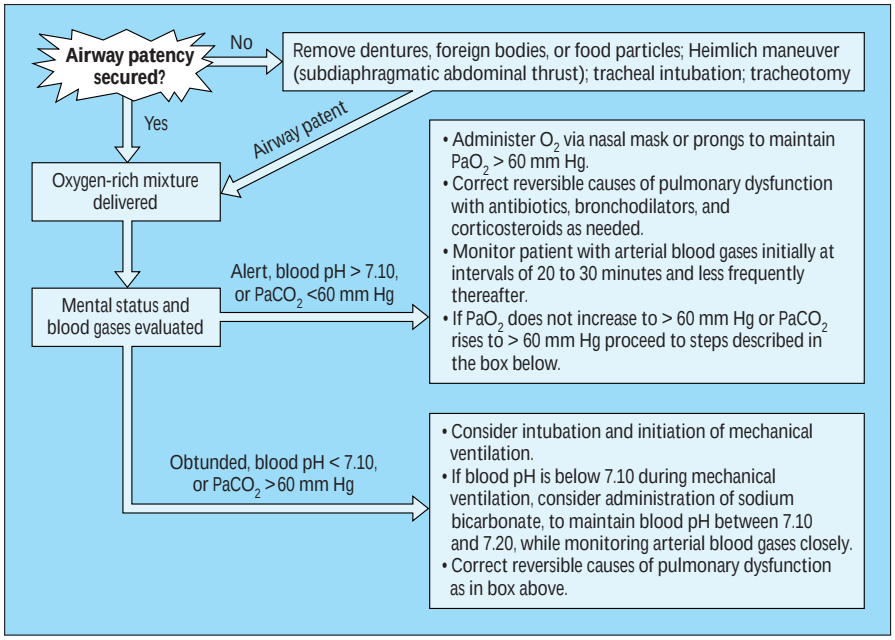

FIGURE 6-7

Acute respiratory acidosis management. Securing airway patency and delivering an oxygen-rich mixture are critical initial steps in management. Subsequent measures must be directed at identifying and correcting the underlying cause, whenever possible [1,9]. $PaCO_2$—arterial carbon dioxide tension.