Mechanisms of Respiratory Failure

66

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I. Respiratory failure is present when there is a major abnormality of gas exchange.
   A. In an adult, the limits of normality are a PaO_2 of >60 Torr (8 kPa).
   B. In the newborn, the oxygen tension needed to maintain the arterial saturation above 90 % varies between 40 and 60 Torr (5.3–8 kPa) depending upon the proportion of hemoglobin that is fetal and the arterial pH (a drop in pH of 0.2 eliminates the left shift produced by 70 % of the hemoglobin being fetal). Thus, in the newborn period, respiratory failure is best defined in terms of oxygen saturation. There are, however, no agreed criteria (see below).
   C. Hypoxia may be associated with hypercarbia ($PaCO_2$ >6.7 kPa or 55 Torr)

$$PaCO_2 \approx \frac{CO_2 \text{ production}}{\text{Alveolar ventilation}}$$

   Alveolar ventilation = (tidal volume − dead space × frequency)
   D. Respiratory failure associated with hypercarbia will occur, therefore, in situations associated with reduction in tidal volume and/or frequency.
   E. Respiratory failure in the neonatal period may be defined as:
   PaO_2 <50 Torr (6.7 kPa) in an inspired oxygen of at least 50 % with/without $PaCO_2$ >50 Torr (6.7 kPa)

II. Hypoxemia in the neonatal period can result from multiple causes
   A. Ventilation/perfusion (V/Q) mismatch
      1. Distinguished by a good response to supplementary oxygen (intrapulmonary shunting)
      2. Increased physiologic dead space, (i.e., loss of gas exchange surface area) found in the following conditions:
         a. Respiratory distress syndrome (RDS)
         b. Pneumonia
         c. Meconium aspiration syndrome
         d. Bronchopulmonary dysplasia
         e. Pulmonary hemorrhage

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B. Extrapulmonary (right-to-left) shunts are distinguished by relatively little improvement with supplementary oxygen and are found in:
   1. Pulmonary hypertension*
   2. Cyanotic congenital heart disease*
C. Methemoglobinemia*
D. Inadequate inspired oxygen*

*Note: although these situations produce cyanosis, this is not from respiratory failure. Cyanosis appears when the reduced hemoglobin concentration of the blood in the capillaries is >5 g/dL. Cyanosis, therefore, does not occur in severe anemic hypoxia (hypoxia is oxygen deficiency at the tissue level).

III. Hypoventilation (reduced alveolar ventilation, reduction in tidal volume and/or frequency) distinguished by a high $PaCO_2$ in association with hypoxemia
   A. Reduced respiratory compliance found in the following conditions:
      1. RDS
      2. Pneumonia
   B. Reduced lung volume found in the following conditions:
      1. RDS
      2. Pulmonary hypoplasia
   C. Compressed lung, found in the following conditions:
      1. Pneumothorax
      2. Congenital diaphragmatic hernia
      3. Pleural effusion
      4. Lobar emphysema
      5. Congenital pulmonary airway malformation
      6. Asphyxiating thoracic dystrophy
IV. Ventilatory pump failure. The ventilatory pump consists of the rigid thoracic cage, the respiratory muscles acting as force generators, and the central nerve system, which coordinate the respiratory muscle activity. Ventilatory pump failure occurs when there is:
   A. Reduced central drive
      1. Maternal opiate treatment (high levels of sedation)
      2. Cerebral ischemia
      3. Intracerebral hemorrhage
      4. Apnea of prematurity
      5. Central alveolar hypoventilation syndrome
   B. Impaired ventilatory muscle function
      1. Drugs (corticosteroids, paralytics—synergism with aminoglycosides)
      2. Disuse atrophy (first signs occur after 1–2 days mechanical ventilation)
      3. Protein calorie malnutrition
      4. Disadvantageous tension–length relationship (e.g., hyperinflation)—diaphragm must contract with a much higher than normal tension. When completely flat, contraction of the diaphragm draws in the lower rib cage, producing an expiratory rather than inspiratory action
      5. Neuromuscular disorders (Werdnig–Hoffman disease, myotonic dystrophy, etc.)
      6. Diaphragmatic problems (e.g., hernia, eventration)
      7. Phrenic nerve palsy (traumatic birth—Erb's palsy)
   C. Increased respiratory muscle workload
      1. Chest wall edema (hydrops)
      2. Upper airway obstruction/endotracheal tube with insufficient compensatory ventilatory support

3. Pulmonary edema, pneumonia
4. Intrinsic (inadvertent) PEEP

V. Disorders affecting the alveolar-capillary interface, distinguished, if incomplete, by a good response to increased supplementary oxygen
   A. Diffusion abnormalities (interstitial lung disease), e.g., pulmonary lymphangiectasia (Noonan syndrome)
   B. Anemia
   C. Alveolar capillary dysplasia

Suggested Reading

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