

# Equations

Minute Ventilation:

$$\dot{V}_E = V_T \times f$$

Physiologic Dead Space:

$$V_D/V_T = (P_{aCO_2} - P_{\bar{E}CO_2})/P_{aCO_2}$$

Alveolar  $PO_2$  (abridged alveolar gas equation):

$$P_{AO_2} = F_{IO_2} \times (P_B - 47) - 1.25 \times P_{aCO_2}$$

Oxygenation Index:

$$OI = [(P_{aw} \times F_{IO_2})/P_{aO_2}] \times 100$$

Shunt:

$$\dot{Q}_s/\dot{Q}_t = (Cc'o_2 - CaO_2)/(Cc'o_2 - C\bar{v}O_2)$$

Oxygen Content:

$$CO_2 = (Hb \times 1.34 \times SO_2) + (0.003 \times PO_2)$$

Henderson-Hasselbalch Equation:

$$pH = 6.1 + \log[HCO_3^-/(0.03 \times P_{aCO_2})]$$

Anion Gap:

$$AG = ([Na^+] + [K^+]) - ([Cl^-] + [HCO_3^-])$$

(because its concentration is small,  $[K^+]$  is often omitted from this calculation)

Respiratory System Compliance (on ventilator):

$$C_{rs} = V_T/(P_{plat} - PEEP)$$

Airway Resistance (on ventilator):

$$R_{aw} = (PIP - P_{plat})/\dot{V}$$

Equation of Motion:

$$P_{aw} + P_{mus} = (\text{Flow} \times \text{Resistance}) + (\text{Volume}/\text{Compliance})$$

Ideal Body Weight:

$$\text{Males: } PBW = 50 + 2.3 \times [\text{Height (inches)} - 60]$$

$$\text{Female: } PBW = 45.5 + 2.3 \times [\text{Height (inches)} - 60]$$

Mean Arterial Blood Pressure (estimate):

$$MAP = [\text{systolic} + (2 \times \text{diastolic})]/3$$

Cardiac Output:

$$\dot{Q}_c = HR \times SV$$

Fick Equation:

$$\dot{Q}_c = \dot{V}_{O_2}/C(a - \bar{v})O_2$$

Cardiac Index:

$$CI = \dot{Q}_c/BSA$$

Systemic Vascular Resistance:

$$SVR = [(MAP - CVP) \times 80]/\dot{Q}$$

Pulmonary Vascular Resistance:

$$PVR = [(MPAP - PCWP) \times 80]/\dot{Q}$$

Cerebral Perfusion Pressure:

$$CPP = MAP - ICP$$

Work of Breathing:

$$W_oB = \int P \times V$$

$$(1 \text{ joule} = 10 \text{ cm H}_2\text{O} \times L)$$

# Abbreviations

**6MWT** six-minute walk test  
**ABG** arterial blood gas  
**A/C** assist/control mode  
**AED** automated external defibrillator  
**AHI** apnea-hypopnea index  
**ACLS** advanced cardiovascular life support  
**AIDS** acquired immunodeficiency syndrome  
**ALI** acute lung injury  
**AP** anteroposterior  
**APRV** airway pressure release ventilation  
**ARDS** acute respiratory distress syndrome  
**ARF** acute respiratory failure  
**BAL** broncho-alveolar lavage  
**BE** base excess  
**BLS** basic life support  
**BNP** brain natriuretic peptide  
**BSA** body surface area  
**BOOP** bronchiolitis obliterans with organizing pneumonia  
**BTPS** body temperature and pressure saturated  
**BUN** blood urea nitrogen  
**BVM** bag-valve-mask  
**CAD** coronary artery disease  
**CAP** community-acquired pneumonia  
**CBC** complete blood count  
**CC** chief complaint  
**CHF** congestive heart failure  
**CI** cardiac index  
**CK-MB** creatinine kinase MB fraction  
**CLD** chronic lung disease  
**CMV** continuous mandatory ventilation  
**CNS** central nervous system  
**COPD** chronic obstructive pulmonary disease  
**CPAP** continuous positive airway pressure  
**CPT** chest physiotherapy  
**CRP** C-reactive protein  
**CSF** cerebral spinal fluid  
**CT** computed tomography  
**CVA** cerebrovascular accident  
**CVP** central venous pressure  
**CXR** chest x-ray  
**DNI** do not intubate  
**DNR** do not resuscitate  
**DPI** dry powder inhaler  
**DRG** diagnosis-related group  
**DVT** deep vein thrombosis  
**EBUS** endobronchial ultrasound  
**ECG** electrocardiograph  
**ECLS** extracorporeal life support  
**ECMO** extracorporeal membrane oxygenation  
**EEG** electroencephalogram  
**EF** ejection fraction  
**EMG** electromyogram  
**EPAP** expiratory positive airway pressure  
**ESS** Epworth Sleepiness Scale  
**ET** endotracheal tube  
**FET** forced expiratory technique  
**HAP** hospital-acquired pneumonia  
**Hb** hemoglobin  
**Hct** hematocrit  
**HCAP** healthcare-associated pneumonia  
**HCO<sub>3</sub>** bicarbonate

**HFCWC** high frequency chest wall compression  
**HFOV** high frequency oscillatory ventilation  
**HIV** human immunodeficiency virus  
**HME** heat and moisture exchanger  
**ICP** intracranial pressure  
**IMV** intermittent mandatory ventilation  
**IS** incentive spirometry  
**iNO** inhaled nitric oxide  
**IBW** ideal body weight (predicted body weight)  
**IPAP** inspiratory positive airway pressure  
**IPF** interstitial pulmonary fibrosis  
**IPPB** intermittent positive pressure breathing  
**IPV** intrapulmonary percussive ventilation  
**LMA** laryngeal mask airway  
**LABA** long-acting  $\beta_2$ -agonist  
**MAP** mean arterial pressure  
**MDI** metered dose inhaler  
**mEq** milliequivalent  
**MI** myocardial infarction  
**MIGET** multiple inert gas elimination technique  
**MRI** magnetic resonance imaging  
**MVV** maximal voluntary ventilation  
**NIH ARDSnet** Acute Respiratory Distress Syndrome Network of the National Institutes of Health  
**NIV** noninvasive ventilation  
**NREM** nonrapid eye movement  
**NSCLC** non-small-cell lung cancer  
**OSA** obstructive sleep apnea  
**PA** posteroanterior  
**PAH** pulmonary arterial hypertension  
**PAP** pulmonary artery pressure  
**PAWP** pulmonary artery wedge pressure  
**PCBF** pulmonary capillary blood flow  
**PC-CMV** pressure-control continuous mandatory ventilation  
**PEP** positive expiratory pressure  
**PEEP** positive end-expiratory pressure  
**PEEPi** intrinsic PEEP (auto-PEEP)  
**PFT** pulmonary function test  
**PI** perfusion index  
**PIE** pulmonary interstitial emphysema  
**PIP** peak inspiratory pressure  
**pMDI** pressurized metered dose inhaler  
**PND** paroxysmal nocturnal dyspnea  
**PPHN** persistent pulmonary hypertension of the newborn  
**Pplat** plateau pressure  
**PPV** positive pressure variation  
**PSV** pressure support ventilation  
**PVC** premature ventricular contraction  
**PVI** plethysmographic variability index  
**PVR** pulmonary vascular resistance  
**RDS** respiratory distress syndrome  
**REE** resting energy expenditure  
**RSBI** rapid shallow breathing index  
**RSI** rapid sequence intubation  
**SABA** short-acting  $\beta_2$ -agonist  
**SCLC** small cell lung cancer  
**SIMV** synchronized intermittent mandatory ventilation  
**SOB** shortness of breath  
**SPN** solitary pulmonary nodule

**SVN** small-volume nebulizer  
**TB** tuberculosis  
**TNF- $\alpha$**  tumor necrosis factor- $\alpha$   
**UAO** upper airway obstruction  
**USN** ultrasonic nebulizer  
**VAP** ventilator-associated pneumonia  
**VATS** video-assisted thoracoscopic surgery  
**VC-CMV** volume-control continuous mandatory ventilation  
**WOB** work of breathing

## Pulmonary and Blood Gas Abbreviations

**Ccw** chest wall compliance  
**Cl** lung compliance  
**Dlco** diffusing capacity of lung for carbon monoxide  
**f** respiratory rate  
**FEV<sub>1</sub>** forced expiratory volume in the first second of expiration  
**FEV<sub>25-75%</sub>** forced expiratory flow, midexpiratory phase, from 25% to 75% of vital capacity  
**FiO<sub>2</sub>** fractional concentration of inspired oxygen  
**FRC** functional residual capacity  
**FVC** forced vital capacity  
**FVL** flow-volume loop  
**Pao<sub>2</sub>** partial pressure of oxygen, arterial  
**PAO<sub>2</sub>** partial pressure of oxygen, alveolar  
**P(A - a)O<sub>2</sub>** alveolar-arterial PO<sub>2</sub> difference  
**P $\bar{v}$ O<sub>2</sub>** mixed venous PO<sub>2</sub>  
**Patm** atmospheric pressure  
**Paw** airway pressure  
**P $\bar{a}$ w** mean airway pressure  
**Pb** barometric pressure  
**PCO<sub>2</sub>** partial pressure of carbon dioxide  
**PEF** peak expiratory flow  
**PE<sub>max</sub>** maximum expiratory pressure  
**PETCO<sub>2</sub>** end-tidal PCO<sub>2</sub>  
**P<sub>I</sub>max** maximum inspiratory pressure  
**Pmus** muscle pressure  
**Ptco<sub>2</sub>** transcutaneous PO<sub>2</sub>  
**Pvent** ventilator pressure  
**P<sub>0.1</sub>** mouth occlusion pressure at 100 msec  
**R** respiratory quotient  
**Raw** airway resistance  
**sGaw** specific airway conductance  
**SpO<sub>2</sub>** oxygen saturation as measured by pulse oximetry  
**SVC** slow vital capacity  
**Te** expiratory time  
**Ti** inspiratory time  
**TLC** total lung capacity  
**Trot** total respiratory cycle time  
**Ve** minute ventilation  
**VC** vital capacity  
**Vco<sub>2</sub>** carbon dioxide production  
**Vd** dead space volume  
**Vo<sub>2</sub>** oxygen consumption  
**Vo<sub>2max</sub>** maximum oxygen consumption  
**V/Q or Va/Q** ventilation-perfusion  
**Vt** tidal volume

# Normal Values

## Vital Signs

Respiratory rate: 12–20 breaths/min in adults;  
60–75 breaths/min in infants  
Heart rate: 60–100 beats/min in adults;  
120–170 beats/min in infants  
Blood pressure: 120/80 mm Hg; lower for infants and children  
Body temperature: 37° C; 98.6° F

## Arterial Blood Gases

pH: 7.35–7.45  
Paco<sub>2</sub>: 35–45 mm Hg  
HCO<sub>3</sub><sup>-</sup>: 22–24 mmol/L  
PaO<sub>2</sub>: 80–100 mm Hg (breathing room air at sea level)  
SaO<sub>2</sub>: 95–98% (breathing room air at sea level)  
P(A – a)O<sub>2</sub>: < 25 mm Hg

## Venous Blood Gases

pH: 7.31–7.41  
Pv̄co<sub>2</sub>: 40–50 mm Hg  
Pv̄o<sub>2</sub>: 35–45 mm Hg  
Sv̄o<sub>2</sub>: 65–75%  
(Ca – v̄)O<sub>2</sub>: 5 mL/dL

## Hemodynamics

Systolic blood pressure: 90–140 mm Hg  
Diastolic blood pressure: 60–90 mm Hg  
Mean arterial pressure: 65–105 mm Hg  
Pulmonary artery systolic pressure: 15–30 mm Hg  
Pulmonary artery diastolic pressure: 4–12 mm Hg  
Mean pulmonary artery pressure: 9–16 mm Hg  
Right ventricular systolic pressure: 15–30 mm Hg  
Right ventricular end-diastolic pressure: 0–8 mm Hg  
Central venous pressure: 0–8 mm Hg  
Pulmonary artery wedge pressure: 2–12 mm Hg  
Cardiac output: 5–8 L/min  
Cardiac index: 2.5–3.5 L/min/m<sup>2</sup>  
Stroke volume: 60–100 mL/beat  
Systemic vascular resistance: 900–1400 dyne × s × cm<sup>-5</sup>  
Pulmonary vascular resistance: 150–250 dyne × s × cm<sup>-5</sup>  
Urine output: 1 mL/kg/hr

## Blood Chemistry

Na<sup>+</sup>: 135–145 mmol/L  
K<sup>+</sup>: 3.5–5.5 mmol/L  
Cl<sup>-</sup>: 98–107 mmol/L  
HCO<sub>3</sub><sup>-</sup>: 22–32 mmol/L  
Ionized Ca<sup>+2</sup>: 1.2–1.3 mmol/L  
Mg<sup>+2</sup>: 0.7–1.1 mmol/L  
PO<sub>4</sub><sup>-</sup>: 0.9–1.5 mmol/L  
Lactate: < 2 mmol/L  
Total protein: 60–80 g/L  
Albumin: 35–55 g/L  
Blood urea nitrogen: 7–21 mg/dL  
Creatinine: 0.7–1.4 mg/dL  
Anion gap: 8–16 mmol/L  
Total bilirubin: < 1.1 mg/dL  
Glucose: 70–110 mg/dL  
Osmolality: 280–300 mOsmol/kg  
Troponin T: < 0.03 ng/mL  
NT-proBNP: < 50 yrs, 0–450 pg/mL; 50–75 yrs,  
0–900 pg/mL; > 75 yrs, 0–1,500 pg/mL  
D-dimer: < 500 ng/mL  
C-reactive protein: < 8 mg/L

## Hematology

Hemoglobin: 13.5–15.5 g/dL for men; 12.5–14.5 g/dL for women  
Hematocrit: 42–52% for men; 37–48% for women  
White blood cell count: 4,000–11,000/mm<sup>3</sup>  
Platelets: 150,000–400,000/mm<sup>3</sup>

## Respiratory Physiology

Tidal volume: 6–7 mL/kg ideal body weight  
Anatomic dead space: 150 mL in adults (2.2 mL/kg)  
Minute ventilation: 6–8 L/min  
V<sub>D</sub>/V<sub>T</sub>: 0.3–0.4  
Shunt: 2–5%  
V̇/Q̇: 0.8  
R: 0.8  
V̇O<sub>2</sub>: 250 mL/min in adults; 3.5 mL/kg/min  
V̇CO<sub>2</sub>: 200 mL/min in adults; 2.8 mL/kg/min  
Lung compliance: 200 mL/cm H<sub>2</sub>O  
Chest wall compliance: 200 mL/cm H<sub>2</sub>O  
Respiratory system compliance: 100 mL/cm H<sub>2</sub>O  
Work of breathing: 0.35 joules/L