Cerebral/Neurologic Formulas

Intracranial pressure (ICP)  
[Normal: <20 cm H2O, <15 mmHg]

Cerebral perfusion pressure (CPP) = MAP – ICP  
[Normal: 70–100 mmHg]

Cerebral vascular resistance (CVR)  
[Normal: 1.5–2.1 mmHg/100 g/min/mL]

Cerebral blood flow (CBF) = CPP/CVR

Hemodynamic Formulas

Pulse pressure = systolic BP – diastolic BP  
[Normal: 70–105 mmHg]

Mean arterial pressure (MAP) = (SBP + 2(DBP))/3  
[Normal: 4–12 mmHg]

Central venous pressure (CVP)  
[Normal: 0–8 mmHg]

Pulse pressure variation = PPV = (PPmax – PPmin)/PPmean  
(Over a respiratory cycle or other period of time; Normal: ≤10%)

Stroke volume variation = SVV = (SVmax – SVmin)/SVmean  
(Over a respiratory cycle or other period of time; Normal: ≤10%)

Mean pulmonary artery pressure (PA)  
[Normal: 10–20 mmHg]

Pulmonary artery occlusion pressure (PAOP)  
[Normal: 4–8 mmHg]

Cardiac output (CO) = Stroke volume (SV) × Heart rate (HR)  
[Normal: 4–8 L/min]

Cardiac index (CI) = CO/BSA  
[Normal: 2.5–4.0 L/min/m²]

Pulmonary vascular resistance (PVR) = (PA – PAOP)/CO  
[Normal: 150–250 dyne/cm²]

Pulmonary vascular resistance index (PVRi) = (PA – PAOP)/CI  
[Normal: 100–240 dyne/cm²/m²]

Systemic vascular resistance (SVR) = (MAP – CVP)/CO  
[Normal: 800–1,200 dyne/cm²]

Systemic vascular resistance index (SVRI) = (MAP – CVP)/CI  
[Normal: 1,300–2,900 dyne/s/cm⁻²/m²]

Stroke volume index (SVI) = CI/HR

Respiratory Formulas

OXYGENATION

Fraction of inspired O₂ (FiO₂)  
[Range: 0.21–1.0]  
[Normal: 75 mL/100 g gray matter/min]

Barometric pressure (PB)  
[760 mmHg at sea level]  
[Normal: 45 mL/100 g white matter/min]

Jugular bulb saturation (SvO₂)  
[Normal: 55–70%]

Cerebral metabolic rate (CMRO₂) = (CBF)(CaO₂ – CjvO₂)  
[Normal: 3–3.5 mL/100 g/min]

Cerebral oxygen extraction = \( \frac{CMO₂}{(CBF)(CaO₂)} - \frac{CaO₂}{CaO₂} \)  
[Normal: 25%]  

Respiratory quotient (R) = VCO₂ expired/VO₂ inspired  
[Normal: 0.8]  

O₂ delivery (DO₂) = CO × CaO₂ × 10  
[Normal: 600–1,000 mL O₂/min]

O₂ consumption (VO₂) = CI(CaO₂ – CjvO₂)  
[Normal: 110–150 mL/min/m²]

O₂ extraction ratio = \( \frac{CaO₂ – CjvO₂}{CaO₂} \)  
[Normal: 25%]
Partial pressure of H2O (PH2O)  
[47 mmHg at 37°C]
Partial pressure of inspired O2 (PIO2)  
[150 mmHg at sea level breathing room air (FIO2 = 0.21)]
Partial pressure of alveolar O2 (PAO2) (alveolar gas equation)

\[
PAO_2 = FIO_2 (PB - PH_2O) - \frac{PaCO_2}{R}
\]

= (FIO2 × 713) – (PaCO2/0.8) (at sea level)
= 150 – (PaCO2/0.8) (at sea level on room air)
[Range: 100 mmHg on room air; 673 mmHg on 100% O2]
Partial pressure of arterial O2 (PaO2)

[Normal: 70–100 mmHg on room air]
Increased: hyperventilation, increased FIO2, contaminated sample
Decreased: hypoventilation, decreased FIO2, V/Q mismatch, intra-pulmonary or anatomic R → L shunt, diffusion abnormalities

Alveolar–arterial O2 gradient (P(A – a)O2) = PAO2 – PaO2

[Normal: 3–16 mmHg on room air; 25–65 mmHg on 100% O2]

LUNG VOLUMES

Tidal volume (VT): Volume inspired/expired with each breath
[Normal: 500 mL; 6–7 mL/kg lean body weight]
Inspiratory reserve volume (IRV): Maximal inspired volume
[Normal: 25% of vital capacity (VC)]
Inspiratory capacity (IC): Maximal volume inspired from resting expiratory level
IC = IRV + VT
[Normal: 1–2.4 L]
Expiratory reserve volume (ERV): Maximal expired volume from end-tidal inspiration
[Normal: 25% of vital capacity (VC)]
Residual volume (RV): Volume remaining in lungs after maximal expiration
[Normal: 1–2.4 L]
Functional residual capacity (FRC): Volume remaining in lungs at end-tidal expiration
FRC = ERV + RV
[Normal: 1–3.4 L]
Vital capacity (VC): Maximal volume expelled by forceful effort after maximal inspiration
VC = IRV + ERV + VT
[Normal: 3–5 L; 50–60 mL/kg lean body weight in females; 70 mL/kg lean body weight in males]
Total lung capacity (TLC): Volume in lungs at end of maximal inspiration
TLC = VC + RV
[Normal: 4–6 L]

Lung Mechanics

Plateau pressure (Pplat)
Peak inspiratory pressure (PIP)
Esophageal pressure (Peso)
Transpulmonary pressure = Pp = Pplat – Pesoph
[Normal: For recruitment Pp = 25 cm H2O; to set PEEP Pp = end-exp = 0 – 5 cm H2O; to set VT or Pp = end-insp = <15 cm H2O]
Positive end-expiratory pressure (PEEP)

Renal Formulas

Creatinine clearance (GCr) = \( \frac{(U_{Creat})(\text{urine volume})}{P_{Creat}} \)
Fractional excretion of sodium (FeNa+):
\[ \frac{\text{urine } [\text{Na}^+] \times \text{plasma } [\text{creatinine}] \times 100}{\text{urine osmolality} \times \text{plasma } [\text{creatinine}]} \]
Free water clearance = urine vol – urine osmolality \times urine vol

Toxicology Formulas

Serum methanol concentration [MeOH] in mg/dL
\[ = 3.2 \times (\text{Osm} - (2 \times [\text{Na}^+]) - ([\text{BUN}] / 2.8) - ([\text{glucose}] / 18) - ([\text{ETOH}] / 4.6) - 10) \]
Ethylene glycol concentration
\[ = 6.2 \times (\text{Osm} - (2 \times [\text{Na}^+]) - ([\text{BUN}] / 2.8) - ([\text{glucose}] / 18) - ([\text{ETOH}] / 4.6) - 10) \]
### Antibiotic Kinetics

The **volume of distribution** ($V_d$) of an antimicrobial is calculated as:

$$V_d = \frac{A}{C_p}$$

where $A =$ total amount of antibiotic in the body and $C_p =$ antibiotic plasma concentration.

Repetitive dosing of antibiotics depends on the principle of **minimal plasma concentrations** ($C_{min}$):

$$C_{min} = \frac{D}{(V_d)(2^n - 1)}$$

where $D =$ dose and $n =$ dosing interval expressed in half-lives.

The **plasma concentration at steady state** ($C_{ss}$) of an antimicrobial can be estimated utilizing the following formula:

$$C_{ss} = \frac{D \times \text{dose per half-life}}{(0.693)(V_d)}$$

### Antibiotic Adjustments

Renal dysfunction in critically ill patients is common. In those patients receiving aminoglycosides, dosage modification is required according to the **aminoglycoside clearance**:

$$C_{cr} (\text{mL/min}) = \frac{(140 - \text{age}) \times \text{weight}}{Cr \times 72}$$

where $Cr =$ serum creatinine in mg/dL. Another modification to this formula is the **Spyker and Guerra method**:

$$C_{cr} (\text{mL/min}) = \frac{(140 - \text{age}) \times (1.03 - 0.053 \times Cr)}{Cr}$$

### Interpretation of Urine Electrolytes

<table>
<thead>
<tr>
<th>Electrolyte</th>
<th>Normal Response</th>
<th>Patient Response</th>
<th>Potential Pitfalls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na⁺</td>
<td>Reflects diet and ECF volume; &lt;10 mmol if ECF volume contracted</td>
<td>&gt;20 mmol in ECF volume contraction suggests renal tubular damage</td>
<td>Diuretic use, No reabsorbed anions, Recent vomiting, drugs</td>
</tr>
<tr>
<td>Cl⁻</td>
<td>Reflects diet and ECF volume; &lt;10 mmol if ECF volume contracted</td>
<td>&gt;20 mmol with ECF volume contraction suggests renal damage</td>
<td>Diuretic, Diarrhea</td>
</tr>
<tr>
<td>K⁺</td>
<td>Reflects diet, plasma (K), aldosterone action</td>
<td>If hypokalemia and urine (K): &gt;20 mM or rate of K excretion &gt;30 mmol/d then K excretion too high</td>
<td>K-sparing diuretics, Low urine (Na), Water diuresis</td>
</tr>
<tr>
<td>pH</td>
<td>Depends on acid-base status; Useful for bicarbonaturia</td>
<td>Useful once low NH₄⁺ excretion confirmed to define cause of low NH₄⁺</td>
<td>Urine tract infection, Urinary tract infection</td>
</tr>
<tr>
<td>HCO₃⁻</td>
<td>Depends on diet and acid-base status; &gt;10 mM indicates HCO₃⁻ load 0 in acidemia</td>
<td>High urine HCO₃⁻ with chronic metabolic alkalosis indicates vomiting or HCO₃⁻ input</td>
<td>Urinary tract infection, Carbonic anhydrase inhibitors</td>
</tr>
<tr>
<td>(Na⁺, K⁺, Cl⁻)</td>
<td>Depends on diet and acid-base status</td>
<td>Na⁺ + K⁺ &gt; Cl⁻</td>
<td>Ketonuria, Drug anionics, Alkaline urine</td>
</tr>
</tbody>
</table>

Na⁺, sodium; Cl⁻, chloride; K⁺, potassium; HCO₃⁻, carbonate; NH₄⁺, ammonia; ECF, extracellular fluid; pRFA, partial renal tubular acidosis.