# Intravenous Fluid & Acid-base Balance for Surgical Patients


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# Objectives

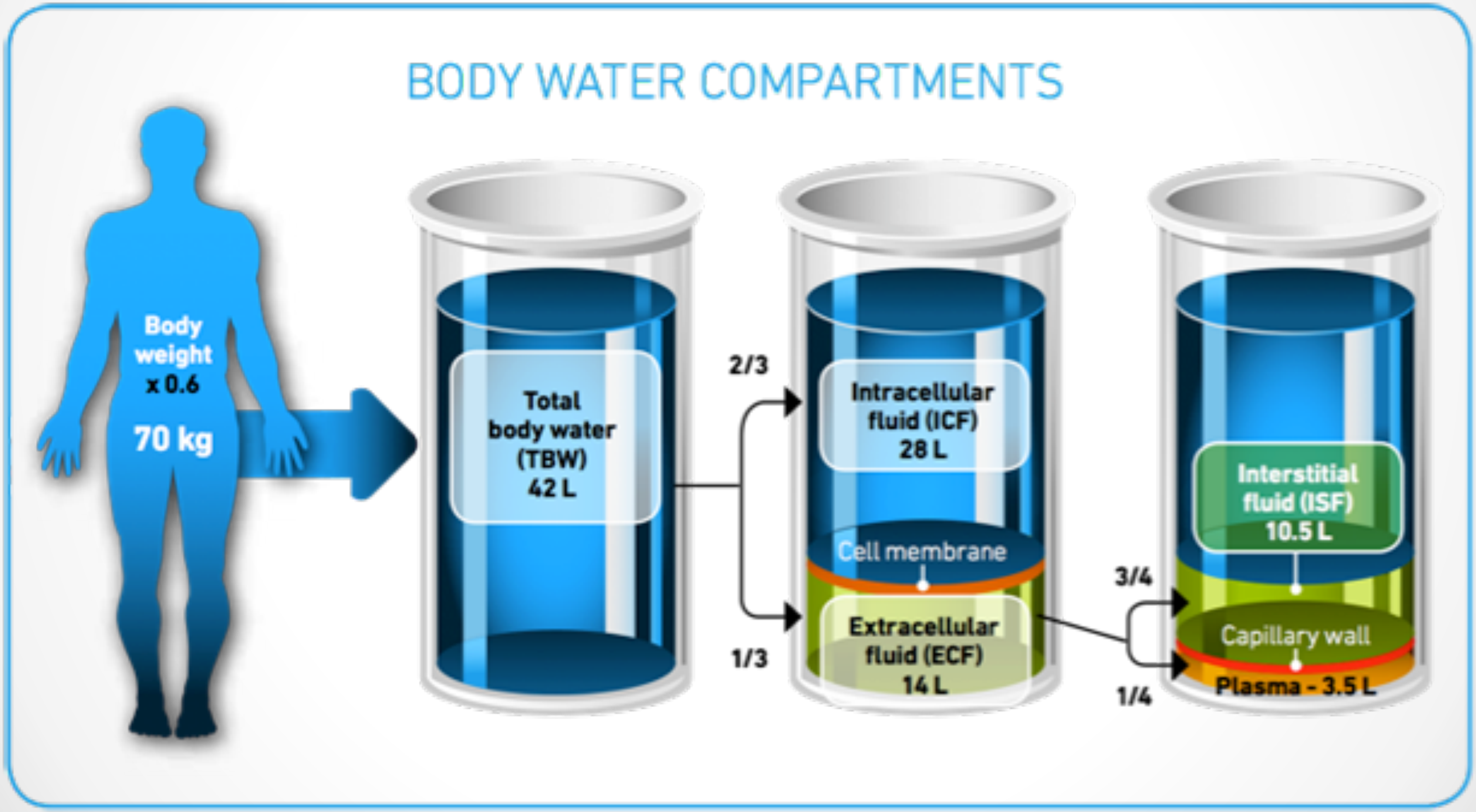
- To explain basics of fluid & electrolytes physiology in surgical patient
- To compare/ contrast different types of commonly used IVF
- To calculate fluid & electrolytes requirement for a patient & choose the appropriate type of fluid
- To discuss different types of electrolytes & fluid disturbance and its management **(self reading)**
- To differentiate between common acid-base disorders **(self reading)**

# What is Intravenous fluid?

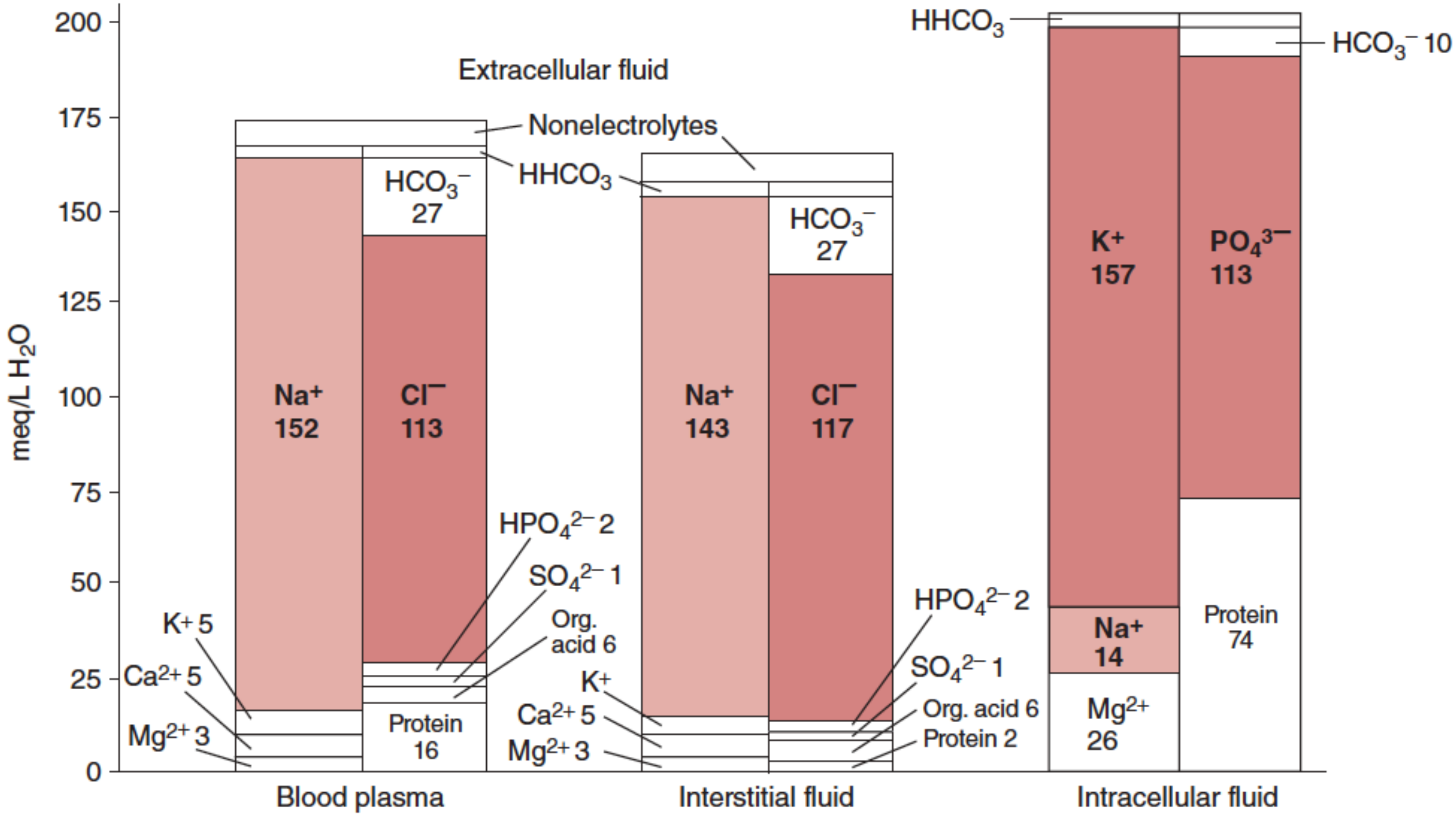
# Why is understanding IV fluid important for you?

- The commonest order prescribed in every hospital
- Needed for almost every patient
- Always done by the junior doctors
- Considered basic medical knowledge
- Everyone expect you to know it
- Incorrect prescription can be very dangerous
- Usually the fluid is available in the floor, so no pharmacist to double check your orders

# Water & electrolyte balance



# Electrolyte composition of the body compartments




▲ **Figure 9–1.** Electrolyte composition of human body fluids. Note that the values are in mEq/L of water, not of body fluid. (From Leaf A, Newburgh LH: *Significance of the Body Fluids in Clinical Medicine*, 2nd ed. Thomas, 1955.)

# Assessing fluid/electrolytes in surgical patient

**Table 1.8 Sources of fluid loss in surgical patients**

| | Typical losses per 24 hrs | Factors modifying volume |
|---|---|---|
| Insensible losses | 700–2000 ml | ↑ Losses associated with pyrexia, sweating and use of non-humidified oxygen |
| Urine | 1000–2500 ml | ↓ With aldosterone and ADH secretion;<br>↑ With diuretic therapy |
| Gut | 300–1000 ml | ↑ Losses with obstruction, ileus, fistulae and diarrhoea (may increase substantially) |
| Third-space losses | 0–4000 ml | ↑ Losses with greater extent of surgery and tissue trauma |

# Assessing fluid/electrolytes in surgical patient

- Effect of Surgery:
  - Stress response:
    - Increased ADH, Aldosteron >> urinary retention + oliguria
  - Third space loss:
    - Surgical manipulation resulting in fluid sequestration within the tissues (extravascular)
  - Loss of fluid from gastrointestinal tract:
    - Bowel obstruction: no fluid absorption
    - Paralytic ileus: loss of GI function after abdominal surgery for 2-3 days
    - Nasogastric tube fluid loss
    - Stoma or intestinal fistula fluid loss
    - Diarrhea

# Volume + Electrolytes in GI fluid

**Table 1.9 The approximate daily volumes (ml) and electrolyte concentrations (mmol/l) of various gastrointestinal fluids***

| | Volume | $Na^+$ | $K^+$ | $Cl^-$ | $HCO_3^-$ |
|---|---|---|---|---|---|
| Plasma | – | 140 | 5 | 100 | 25 |
| Gastric secretions | 2500 | 50 | 10 | 80 | 40 |
| Intestinal fluid (upper) | 3000 | 140 | 10 | 100 | 25 |
| Bile and pancreatic secretions | 1500 | 140 | 5 | 80 | 60 |
| Mature ileostomy | 500 | 50 | 5 | 20 | 25 |
| Diarrhoea (inflammatory) | – | 110 | 40 | 100 | 40 |

# IVF administration

- Before ordering IVF, you should ask yourself:
  - How much maintenance fluid does the patient need?
    - **4,2,1 formula**
  - Is there any fluid deficit I should add?
    - Dehydrated patient!
  - What fluid compartment I want to replace?
  - Does the patient have any electrolytes disturbance?
    - Na, K, Cl
  - What is the type of fluid appropriate for my patient?
    - Crystalloid vs. colloid
  - Does the patient need bolus or continuous fluid?

# How to calculate daily fluid requirement (maintenance)?

- 3 methods:
  1. 4,2,1 formula (most commonly used)- ml/hr
  2. 35 ml/kg/day (rough estimate)
  3. Weight + 40 ml/hr

# Normal daily fluid requirement (maintenance)

| Method 1: 4,2,1 formula: based on body weight | |
|---|---|
| First 10 kg | 4ml/kg/hr |
| Next 10kg | 2ml/kg/hr |
| Each kg over 20kg | 1ml/kg /hr |

- Example: Calculate the fluid requirement of a 100kg-man
- First 10 kg: 4x10= 40
- Next 10kg: 2x10= 20
- Last 80kg: 1x80= 80
- Total: 40+20+80= 140ml/hr =3360ml/day

# Normal daily fluid requirement (maintenance)

- Method 2: 35 ml/kg/day
  - 35 x 100= 3500 ml/kg/day = 145 ml/hr

- Method 3: Weight + 40 ml/hr
  - 100 + 40= 140 ml/hr

# Types of IV fluids

- Crystalloids:
  - Dextrose solutions
  - NaCl solutions
    - 0.9% normal saline
    - ½ normal saline
    - ¼ normal saline
    - Hypertonic saline
  - Ringer's Lactate (Hartmann's solution)

- Colloids:
  - Natural: albumin
  - Synthetic: Gelatins, Hetastarch, Dextran

# Crystalloids

- Dextrose fluids:
  - Different concentration: 5%, 10%, 20%, 50%
  - 5% Dextrose contain 5gm of glucose in every 100ml of water (50g/L)
  - No electrolytes
  - After administration:
    - 60% will go to intarcellular compartment
    - 30% will go to extracellular compartment (80% Interstitial , 20% intravascular)
  - Not good option for fluid resuscitation
  - > 12% dextrose can not be administered in peripheral vein (central venous line is needed)
  - Never bolus any dextrose containing solution !!! (hypotonic)

# Crystalloids

- Electrolytes solutions:
  - NaCl solutions (0.9% NS, ½ NS, ¼ NS)
  - LR solution (Hartmann's)
  - Types:
    - Hypotonic fluid: 1/2NS, ¼ NS
      - Never bolus a hypotonic solution!!!
    - Isotonic fluids:
      - 0.9%NS, LR **(similar osmolality to plasma)**
      - 25% will remain in the IVC
      - 75% will go to EVC
      - Best option for fluid resuscitation e.g. dehydration, trauma, perioperative
      - <u>Can be given as bolus or continuous fluid</u>
    - Hypertonic solutions
      - E.g. 3% NS
      - Rarely used ( for cerebral edema and management of brain injuries)

# Composition of IV fluid

**Table 1.10 Composition of commonly administered intravenous fluids**

| | $Na^+$ (mmol/l) | $K^+$ (mmol/l) | $Cl^-$ (mmol/l) | $HCO_3^-$ (mmol/l) | $Ca^{2+}$ (mmol/l) | $Mg^{2+}$ (mmol/l) | Oncotic pressure ($mmH_2O$) | Typical plasma half-life | pH |
|---|---|---|---|---|---|---|---|---|---|
| 5% dextrose | – | – | – | – | – | | 0 | – | 4.0 |
| 0.9% NaCl | 154 | 0 | 154 | 0 | 0 | | 0 | – | 5.0 |
| Ringer's lactate (Hartmann's solution) | 131 | 5 | 112 | 29* | 1 | 1 | 0 | – | 6.5 |
| Haemaccel (succinylated gelatin) | 145 | 5.1 | 145 | 0 | 6.25 | | 370 | 5 hours | 7.4 |
| Gelofusine (polygeline gelatin) | 154 | 0.4 | 125 | 0 | 0.4 | 0.4 | 465 | 4 hours | 7.4 |
| Hetastarch | 154 | 0 | 154 | 0 | 0 | | 310 | 17 days | 5.5 |
| Human albumin solution 4.5% (HAS) | 150 | 0 | 120 | 0 | 0 | | 275 | – | 7.4 |

# Composition of IV fluid

| | Na (mEq/L) | K (mEq/L) | Cl (mEq/L) | HCO3 (mEq/L) | Dextrose (gm/L) | mOsm/L |
|---|---|---|---|---|---|---|
| D5W | | | | | 50 | 278 |
| ½ NS | 77 | | 77 | | | 143 |
| D51/2NS | 77 | | 77 | | 50 | 350 |
| NS | 154 | | 154 | | | 286 |
| D5NS | 154 | | 154 | | 50 | 564 |
| Ringers Lactate (RL) | 130 | 4 | 109 | 28 | 50 | 272 |


# Colloids

- Examples:
  - Natural: albumin 5%, 20%
  - Synthetic: Gelatins, Hetastarch, Dextran
- Contain protein particles that exert oncotic pressure and cause fluid to remain in the intravascular compartment for ~ 6-24hrs
- Disadvantages of colloid:
  - Not widely available
  - Take time to prepare and administer
  - Albumin is a blood product (stored in the blood bank)
  - Expensive
  - Can cause allergic reactions, pruritus, coagulopathy

# Which goes to which?

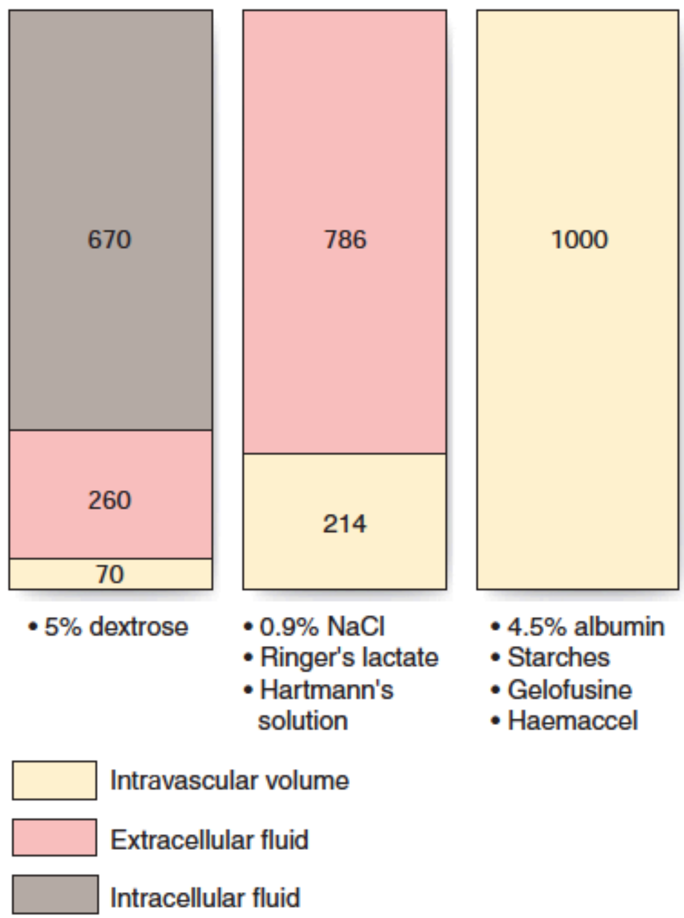



**Fig. 1.6** Distribution of different fluids in the body fluid compartments 30–60 minutes after rapid intravenous infusion of 1000 ml.

- Is colloid better than crystalloid for fluid resuscitation?

| EBM | 1.1 Crystalloid vs colloid to treat intravascular hypovolaemia |
| --- | --- |
| | *'There is no evidence that resuscitation with colloids reduces the risk of death, compared to resuscitation with crystalloids, in patients with trauma, burns or following surgery.'* |
| | Perel P. et al., Cochrane Database Syst Rev. 2007 Oct 17;(4):CD000567 |
| | *'The use of 4% albumin for intravascular volume resuscitation in critically ill patients is associated with similar outcomes to the use of normal saline.'* |
| | Finfer S. et al. The SAFE study. New Engl J Med 2004; 350:2247–2256. |

# Electrolyte requirement

- Adult:
  - Na: 1-2 mEq/kg/day
  - K: 1mEq/kg/day
  - Cl 1-2mEq/kg/day
- Children:
  - Na: 2-3 mEq/kg/day
  - K: 2-3 mEq/kg/day
  - Cl: 2-3 mEq/kg/day

# Calculating fluid requirement for 70kg adult

- Assuming normal, well hydrated patient, normal electrolytes
- Volume: 4,2,1 formula
  - (4x10) + (2x10) + (1x50) = 110 ml/hr
  - 2640 ml/day
- Electrolytes:
  - Na: 1-2 x 70= 70-140 mEq/day
  - K: 1x70= 70 mEq/day
- Type of fluid:
  - D5 1/2 NS is the best solution
  - Why:
    - If you give 0.9NS only = 400mEq/day of Na (too much)
    - If you give ½ NS only = 200mEq/day of Na (acceptable)
    - But 1/2NS is hypotonic (150mOsmol/L) >> add D5 will raise osmolality to 400 mOsm (acceptable) also will prevent muscle catabolism
  - You should add 20mEq KCL/L to the solution = 52 mEq/day

# Your final order:
# Start IV fluid D51/2 NS + 20mEq KCL/L @ 110ml/hr

# Water & electrolytes disturbance

# Water depletion/ Dehydration

- Very common in surgical patients
- Usually water + Na
- Commonly caused by:
  - Decreased intake
  - Increased GI loss (diarrhea, vomiting, NGT loss, high stoma output)m;987
- Signs of dehydration:
  - Decreases skin turgor
  - Dry mucous membranes
  - Tachycardia
  - Oliguria <500ml/day (normal 0.5-1ml/kg/hr)
  - Hypotension
  - Decreased level of consciousness
- Treatment:
  - Rapid IV bolus of isotonic solution (0.9% NS or LR)
  - 250-1000ml over 30-60min
  - Monitor response to rehydration

# Water excess

- Due to excessive fluid administration (especially hypotonic fluid e.g. Dextrose solutions
- Can cause hyponatremia (dilutional)
- Water accumulate in ECC
- Difficult to detect clinically (edema, basal chest crackles, elevated JVP)
- Later stages >> tissue edema
- High risk patients:
  - Cardiac failure
  - Renal failure

# Hypernatremia (Na >145mmol/l)

## Causes

**Hypovolaemic**
- ↓ oral intake (e.g. fasting, ↓ conscious level) *
- Nausea and vomiting*
- Diarrhoea*
- ↑ Insensible losses (↑ sweating and/or ↑ respiratory tract losses)
- Severe burns*
- Diuresis (e.g. glycosuria, use of osmotic diuretics)

**Euvolaemic**
- Diabetes insipidus – central or nephrogenic

**Hypervolaemic**
- Excessive sodium load (hypertonic saline, TPN, sodium bicarbonate)
- ↑Mineralocorticoid activity (e.g. Conn's syndrome or Cushing's disease)

## Treatment

- Hypovolemic hyponatremia is treated with isotonic saline
- Avoid rapid lowering Na (cerebral edema, permanent brain damage)

# Hyponatremia (Na <135 mmol/L)

## Causes

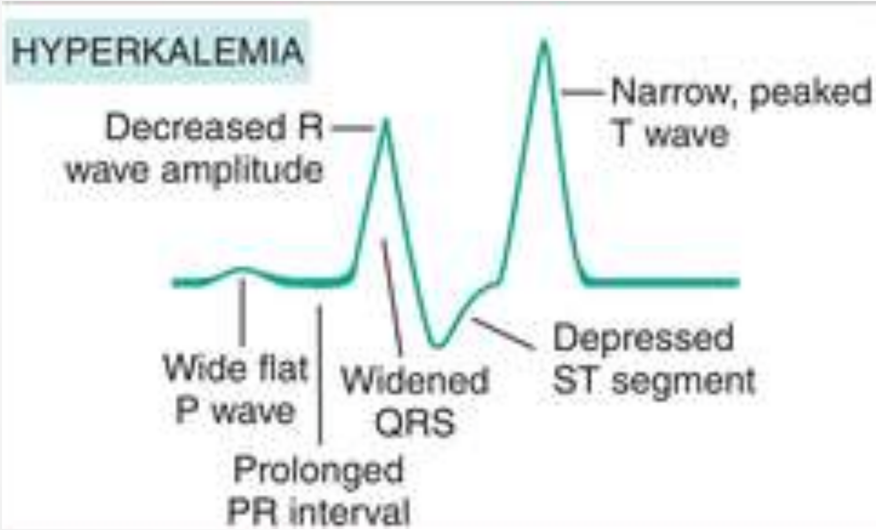
| | |
|---|---|
| **Low extracellular fluid volume** | • Diarrhoea*<br>• Diuretic use*<br>• Adrenal insufficiency<br>• Salt-losing renal disease |
| **Normal extracellular fluid volume** | • Syndromes of inappropriate ADH secretion (SIADH)<br>• Hypothyroidism<br>• Psychogenic polydipsia |
| **Increased extracellular fluid volume** | • Excessive water administration*<br>• Secondary hyperaldosteronism (cirrhosis, cardiac failure)<br>• Renal failure. |

## Treatment

- Depends of extracellular fluid volume status:
  - Normal or high: reduce water intake> Na will correct
  - Low: isotonic fluid administration
- Avoid rapid correction >> brain damage

# Hyperkalemia K>5mmol/l

- Can be life threatening




| Hyperkalaemia |
|---|
| **Consequences** |
| • Arrhythmias (tented T waves, ↓ HR, heart block, broadened QRS, asystole)<br>• Muscle weakness<br>• Ileus |
| **Causes** |
| **Excess intravenous or oral intake** |
| **Transcellular shift – efflux of potassium from cells** |
| • Metabolic acidosis*<br>• Massive blood transfusion*<br>• Rhabdomyolysis (e.g. crush and/or compartment syndromes)*<br>• Massive tissue damage (e.g. ischaemic bowel or liver)*<br>• Drugs (e.g. digoxin, β-receptor antagonists) |
| **Impaired excretion** |
| • Acute renal failure*<br>• Chronic renal failure<br>• Drugs (ACE inhibitors, spironolactone, NSAIDs)<br>• Adrenal insufficiency (Addison's disease). |

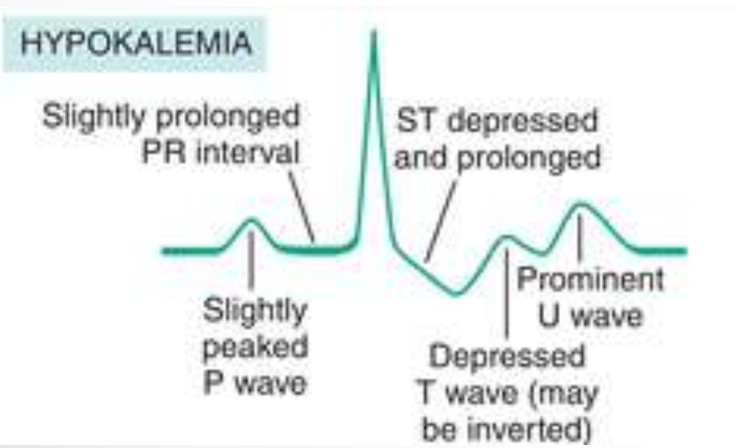
# Hyperkalemia K>5mmol/l

**Table 1.13 Management of severe hyperkalaemia ($K^+$ >7 mmol/l)**

| | |
|---|---|
| 1. Identify and treat cause. Monitor ECG until potassium concentration controlled. | |
| 2. 10 ml 10% calcium gluconate iv over 3 mins, repeated after 5 min if no response | Antagonizes the membrane actions of ↑ $K^+$ reducing the risk of ventricular arrhythmias |
| 3. 50 ml 50% dextrose + 10 units short-acting insulin over 2–3 mins. Start infusion of 10–20% dextrose at 50–100 ml/h | Increases transcellular shift of $K^+$ of into cells |
| 4. Regular salbutamol nebulizers | Increases transcellular shift of $K^+$ of into cells |
| 5. Consider oral or rectal calcium resonium (ion exchange resin) | Facilitates $K^+$ clearance across gastrointestinal mucosa. More effective in non-acute cases of hyperkalaemia |
| 6. Renal replacement therapy | Haemodialysis is the most effective medical intervention to lower $K^+$ rapidly |

# Hypokalemia K< 3mmol/l

- Very common in surgical patients
- Most K is lost via kidneys
- Rx:
  - Oral K
  - IV K for severe cases
  - Avoid K IV bolus (arrhythmia)




| Hypokalaemia |
| --- |
| |
| • ECG changes (flattened T-waves, U-waves, ectopics)<br>• Muscle weakness and myalgia |
| |
| **Inadequate intake*** |
| **Gastrointestinal tract losses** |
| • Vomiting*<br>• Gastric aspiration/drainage*<br>• Fistulae*<br>• Diarrhoea*<br>• Ileus*<br>• Intestinal obstruction*<br>• Potassium-secreting villous adenoma* |
| **Urinary losses** |
| • Metabolic alkalosis*<br>• Hyperaldosteronism*<br>• Diuretics*<br>• Renal tubular disorders (e.g. Bartter's syndrome, renal tubular acidoses, drug-induced) |
| **Transcellular shift–influx of potassium into cells**<br>• Metabolic alkalosis*<br>• Drugs* (e.g. insulin, β-agonists, adrenaline). |

# Acid-base balance & common disorders

# Introduction

- pH: measure of fluid acidity
- Normal plasma values:
  - pH: 7.35-7.45
  - PCo2: 35-45 mmHg
  - HCo3: 22-26
- Acidosis:
  - pH <7.35
  - Can be respiratory or metabolic
- Alkalosis:
  - pH >7.45
  - Can be respiratory or metabolic
- Arterial blood gas (ABG) is the method to analyze acid-base status through arterial blood sample from the radial artery

**Fig. 1.7** A blood gas sample being taken from the radial artery under local anaesthesia.

# ABG result

| | | | |
|---|---|---|---|
| **Blood Gas Values** | | | |
| ↓ pH | 6.956 | | [ 7.350 - 7.450 ] |
| ↑ $pCO_2$ | 155 | mmHg | [ 35.0 - 45.0 ] |
| ↓ $pO_2$ | 35.0 | mmHg | [ 75.0 - 100 ] |
| **Acid Base Status** | | | |
| $cHCO_3^-(P,st)_c$ | 22.5 | mmol/L | |
| $cBase(B)_c$ | -1.5 | mmol/L | [ -3.0 - 3.0 ] |
| **Electrolyte Values** | | | |
| ↑ $cK^+$ | 5.7 | mmol/L | [ 3.4 - 5.5 ] |
| $cNa^+$ | 144 | mmol/L | [ 136 - 146 ] |
| $cCa^{2+}$ | 1.30 | mmol/L | [ 1.15 - 1.30 ] |
| ? $cCa^{2+}(7.4)_c$ | | mmol/L | |
| ↑ $cCl^-$ | 107 | mmol/L | [ 94 - 107 ] |
| **Metabolite Values** | | | |
| ↑ cGlu | 10.2 | mmol/L | [ 3.9 - 5.8 ] |
| cLac | 1.2 | mmol/L | [ 0.5 - 2.0 ] |
| **Oxygen Status** | | | |
| ↓ ctHb | 81 | g/L | [ 130 - 180 ] |
| ↓ $sO_2$ | 46.0 | % | [ 95.0 - 100.0 ] |
| $p50_c$ | 37.16 | mmHg | |
| $pO_2(a/A)_e$ | 6.3 | % | |
| FMetHb | 0.1 | % | [ 0.0 - 1.5 ] |
| FCOHb | 1.2 | % | [ 0.0 - 1.5 ] |
| $p50(st)_c$ | 22.64 | mmHg | |
| $FShunt_e$ | 59.4 | % | |
| $FO_2Hb$ | 45.4 | % | [ - ] |
| $Hct_c$ | 25.2 | % | |

# How to read blood gas?

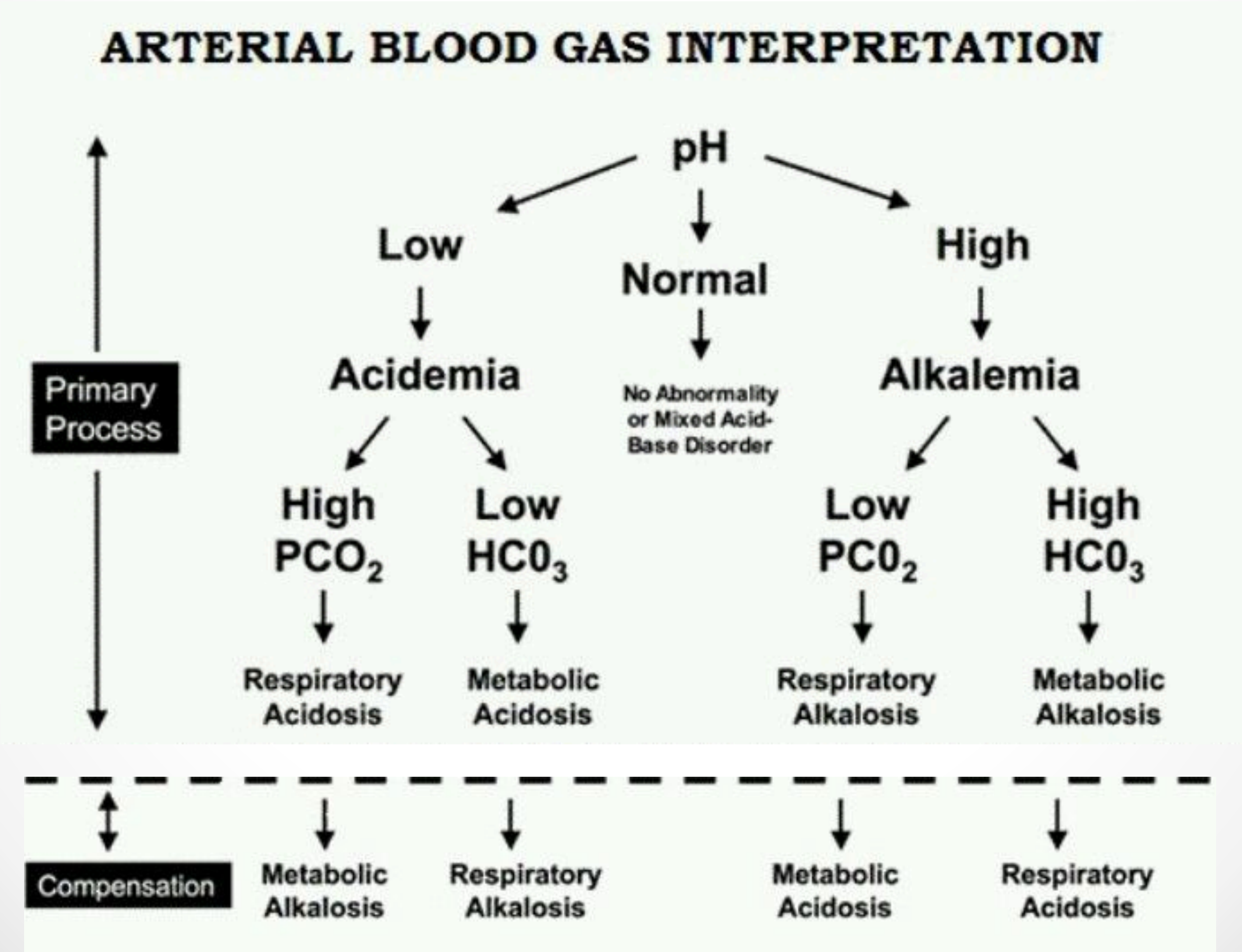


**Table 9–3.** Changes in $HCO_3^-$ and $pCO_2$ in primary acid-base disorders.

| Disorder | pH | $HCO_3^-$ | $Pco_2$ |
|---|---|---|---|
| Metabolic acidosis | ⇓ | ⇓ | ⇓ (compensatory) |
| Metabolic alkalosis | ⇑ | ⇑ | ⇑ (compensatory) |
| Respiratory acidosis | ⇓ | ⇑ (compensatory) | ⇑ |
| Respiratory alkalosis | ⇑ | ⇓ (compensatory) | ⇓ |

# Metabolic Acidosis

**Common surgical causes**

**Lactic acidosis**
- Shock (any cause)
- Severe hypoxaemia
- Severe haemorrhage/anaemia
- Liver failure

**Accumulation of other acids**
- Diabetic ketoacidosis
- Starvation ketoacidosis
- Acute or chronic renal failure
- Poisoning (ethylene glycol, methanol, salicylates)

**Increased bicarbonate loss**
- Diarrhoea
- Intestinal fistulae
- Hyperchloraemic acidosis

**Acid–base findings**

**Acute uncompensated**
- $H^+$ ions ↑
- $P_aCO_2$ ↔
- Actual $HCO_3^-$ ↓
- Standard $HCO_3^-$ ↓
- Base deficit < −2

**With respiratory compensation (hyperventilation)**
- $H^+$ ions ↔ (full compensation) ↑ (partial compensation)
- $P_aCO_2$ ↓
- Actual $HCO_3^-$ ↓
- Standard $HCO_3^-$ ↓

# Metabolic alkalosis

**Metabolic alkalosis**

| **Common surgical causes** |
| --- |
| **Loss of sodium, chloride and water**<br>• Vomiting<br>• Loss of gastric secretions<br>• Diuretic administration |
| **Hypokalaemia** |

| **Acid–base findings** |
| --- |
| **Acute uncompensated**<br>• $H^+$ ions ↓<br>• $P_aCO_2$ ↔<br>• Actual $HCO_3^-$ ↑<br>• Standard $HCO_3^-$ ↑<br>• Base excess > + 2 |
| **With respiratory compensation (hypoventilation)**<br>• $H^+$ ions ↔ (full compensation), ↓ (partial compensation)<br>• $P_aCO_2$ ↑<br>• Actual $HCO_3^-$ ↑<br>• Standard $HCO_3^-$ ↑ |

# Respiratory Acidosis

**Respiratory acidosis**

| Common surgical causes |
| --- |
| **Central respiratory depression**<br>• Opioid drugs<br>• Head injury or intracranial pathology |
| **Pulmonary disease**<br>• Severe asthma<br>• COPD<br>• Severe chest infection |
| **Acid–base findings** |
| **Acute uncompensated**<br>• $H^{+}$ ions ↑<br>• $P_aCO_2$ ↑<br>• Actual $HCO_3^-$ ↔ or ↑<br>• Standard $HCO_3^-$ ↔<br>• Base deficit $< -2$ |
| **With metabolic compensation (renal bicarbonate retention)**<br>• $H^{+}$ ions ↔ (full compensation), ↑ (partial compensation)<br>• $P_aCO_2$ ↑<br>• Actual $HCO_3^-$ ↑<br>• Standard $HCO^-$ ↑↑ |

# Respiratory alkalosis

**Respiratory alkalosis**

| Common surgical causes |
| --- |
| • Pain<br>• Apprehension/hysterical hyperventilation<br>• Pneumonia<br>• Central nervous system disorders (meningitis, encephalopathy)<br>• Pulmonary embolism<br>• Septicaemia<br>• Salicylate poisoning<br>• Liver failure |
| **Acid–base findings** |
| **Acute uncompensated**<br>• $H^+$ ions ↓<br>• $P_aCO_2$ ↓<br>• Actual $HCO_3^-$ ↔ or ↓<br>• Standard $HCO_3^-$ ↔<br>• Base excess > + 2 |
| **With metabolic compensation (renal bicarbonate excretion)**<br>• $H^+$ ions ↔ (full compensation), ↓ (partial compensation)<br>• $P_aCO_2$ ↓<br>• Actual $HCO_3^-$ ↓<br>• Standard $HCO_3^-$ ↓ |

# THANK YOU

- REMEMBER:
  - Formula to calculate fluid requirement
  - Comparing different types of fluid
  - Identifying and managing dehydrated patient
  - Composition of different intravenous solutions

- For Questions: