Acid-Base Problems on the Acute Take

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Not everything that’s sour is sweet..

• How to approach acid-base disorders

• The liver and lactate metabolism

• The RAA system in acid-base disorders
# Daily acid generation (burden)

<table>
<thead>
<tr>
<th>Type</th>
<th>Daily amount</th>
<th>Route of elimination</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>15 mol/day</td>
<td>Lungs</td>
</tr>
<tr>
<td>Lactate</td>
<td>1.2 mol/day</td>
<td>Liver, kidneys</td>
</tr>
<tr>
<td>Ketoacids</td>
<td>0.6 mol/day</td>
<td>Many; urine</td>
</tr>
<tr>
<td>FFAs</td>
<td>0.7 mol/day</td>
<td>Many</td>
</tr>
<tr>
<td>Urea</td>
<td>1.1 mol/day</td>
<td>Liver and others</td>
</tr>
</tbody>
</table>

Most disturbances shift towards acidaemia
Henderson Hasselbach Equation

\[
pH = 6.1 + \log_{10} \frac{\text{bicarbonate}}{0.225 \times \text{PCO}_2}
\]

Simplified: \([\text{H}^+]\) is proportional to \(\frac{\text{[CO}_2]}{\text{HCO}_3}\)
An Approach to Acid Base Disorders

- You can’t “over-compensate” a disturbance of pH but you can have a mixed acid-base disorder.
An Approach to Acid Base Disorders

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• In a metabolic acidosis, the next step is to calculate the anion gap.
An Approach to Acid Base Disorders

• You can’t “over-compensate” a disturbance of pH but you can have a mixed acid-base disorder.
• In a metabolic acidosis, the next step is to calculate the anion gap.
• In a metabolic alkalosis, the next step is to assess the volume status.
Metabolic Acidosis

• Categorised according to the anion gap

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

Normally 10-18 mEq/L.

• Albumin has a net negative charge. It is the major unmeasured anion.
The Anion Gap

- **High** anion gap:
  Replacement of $\text{HCO}_3^-$ by unmeasured organic acids e.g. lactate, hydroxybutyrate; other organic acids accumulating in uraemia
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  Replacement of $\text{HCO}_3^-$ by unmeasured organic acids e.g. lactate, hydroxybutyrate; other organic acids accumulating in uraemia

- **Normal** anion gap:
  Loss of alkaline GI secretions: diarrhoea
  Renal tubular defect in $\text{HCO}_3^-$ reuptake or $\text{H}^+$ excretion: RTA
Liver and acid base

**Conclusion**

Metabolism of lactate consumes acid and generates bicarbonate

\[ \text{OH}^- + \text{CO}_2 \rightarrow \text{HCO}_3^- \]

\[ 2\text{CH}_3\text{CHOHCOO}^- + 2\text{H}^+ \rightarrow \text{Glucose} \]

(gluconeogenesis)
LACTIC ACIDOSIS

• Raised anion gap acidosis with plasma lactate > 4 meq/L

• Commonest cause of metabolic acidosis in hospitalised patients

• Type A - due to immediate effects of shock

• Type B - due to impaired cellular metabolism
LACTIC ACIDOSIS

Lactic acidosis $\rightarrow$ blood pH falls

Gluconeogenesis from lactate inhibited $\rightarrow$ Liver cell pH falls
LACTIC ACIDOSIS

(Gluconeogenesis) → Glucose → Pyruvate → (Glycolysis)

Inhibited by metformin at high plasma concentrations

Lactate + 2H⁺
LACTIC ACIDOSIS: treatment

- Treat the cause: restore tissue perfusion
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- Bicarbonate Therapy: beware!
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LACTIC ACIDOSIS: treatment

• Treat the cause: restore tissue perfusion
• Bicarbonate Therapy: beware!
• Consider in patients with pH less than 7.1 with haemodynamic instability who are adequately ventilated
• Recognise that a bolus of Na Bicarbonate will cause:
  - elevation pCO2
  - fall ionised Calcium
  - rapid rise in serum Na and ECF volume
Acid base: case 1

- 45 year old man
- Drowsy, abdominal pain
- Recent alcohol binge
- No history diabetes; no FH diabetes
- Signs of alcoholic liver disease
- Capillary blood glucose 1.5mmol/l
Acid Base Case 1

Investigations: Capillary blood glucose 1.5mmol/l
\[ \text{pH} \ 7.2 \]
\[ \text{pCO2} \ 3.1 \text{ kPa} \]
\[ \text{pO2} \ 13 \text{ kPa} \]
\[ \text{HCO3} \ 19 \text{ mmol/L} \]
\[ \text{Lactate} \ 1\text{mEq/L} \]
Acid Base Case 1

Investigations: Capillary blood glucose 1.5mmol/l
- pH 7.2
- pCO2 3.1 kPa
- pO2 13 kPa
- HCO3 19 mmol/L
- Lactate 1mmol/L

Anion gap 25 mmol/L
High anion gap acidosis

What is the exogenous acid?
High anion gap acidosis

What is the exogenous acid?

KETONES
Alcoholic Ketoacidosis

- Starved state: promotes ketoacid production
Alcoholic Ketoacidosis

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- Alcohol dehydrogenase requires NAD$\rightarrow$$\rightarrow$NADH
- NAD$\rightarrow$$\rightarrow$NADH also required for hepatic gluconeogenesis
Alcoholic Ketoacidosis

- Starved state: promotes ketoacid production
- Alcohol dehydrogenase requires NAD>>NADH
- NAD>>NADH also required for hepatic gluconeogenesis
- Treatment: iv Dextrose with generous K supplementation. Thiamine.
Acid Base Case 2

- 56 male
- Referred from GP with raised K on routine tests
- No relevant medications
- T2DM retinopathy, sensory neuropathy
Acid Base Case 2

Investigations

Na 140
K 6.5
Creatinine 140
pH 7.2
HCO3 19
Glucose 12
Acid Base Case 2

Investigations

Na 140 mmol/l
K 6.5 mmol/l
Creatinine 140 mmol/l
pH 7.2
HCO3 19 mmol/l
Glucose 12 mmol/l

Anion Gap 10mmol/l
Normal Anion Gap Acidosis

- No GI bicarbonate loss
- Must be a renal tubular defect
Renal tubular acidosis

- Type 1 (distal): can’t maintain a high gradient of $H^+$ between tubular lumen and blood. Urine pH $> 5.3$

- Type 2 (proximal). Can’t reabsorb filtered $HCO_3^-$ until blood $HCO_3^- < 12$ mmol/l. Then urine pH falls to $< 5.3$

- Type 4 - hypoaldosteronism

- All may be hyperchloraemic: Cl reabsorbed instead of $HCO_3^-$
Type 4 RTA

- Normal 9am cortisol
- Low plasma renin activity
- Low serum aldosterone
- Manifestation of autonomic neuropathy most commonly seen in patients with DM
- Treatment: Fludrocortisone
Metabolic Alkalosis

• Source of excess HCO3 or H+ loss
  +
• Defect in renal excretion of excess bicarbonate

• History
• Intravascular volume status
Metabolic Alkalosis with Volume Contraction

GI:
Loss of acidic secretions from vomiting, NG tube, laxatives

Renal:
Diuretics
Genetic disorders involving renal tubular transport: Bartter’s syndrome, Gitelman’s syndrome
Metabolic Alkalosis without Volume Contraction

Primary mineralocorticoid excess: Conn’s Syn
Mimics of MC excess: liquorice, ectopic ACTH

Administration of NaHCO3

Administration of organic anion salts that are metabolised to bicarbonate eg Na lactate
Acid base: case 3

- 67 year old female
- Bilateral hydronephrosis: iv fluid and JJ stents
- Referred with carpopedal spasm
- BP Normal
- Serum total calcium: 2.36 mmol/L
Acid base: case 3

ABG:  
pH 7.75
pCO₂ 6.1 kPa
pO₂ 12.2 kPa
HCO₃ 39 mmol/L
Lactate 4.9 mmol/L (0.6-1.8 mmol/L)
Serum ionised calcium: 0.9 mmol/L (LOW)

Metabolic Alkalosis with high Lactate
Acid base: case 3

ABG:
- pH 7.75
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Metabolic Alkalosis with high Lactate
Not Volume contracted normotensive
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Metabolic Alkalosis with high Lactate
Not Volume contracted normotensive
Source of Exogenous Bicarbonate?
Acid base: case 3

- Review of IV chart:
  6 litres of Hartmann’s solution over 48 hours
  ≡ large amount of bicarbonate
Acid-base case 4

- 23 year old female
- Seizures
- 2 day history occasional vomiting
- No medications
- No past medical surgical history
- BP 20mmHg postural drop
Acid-base case 4

• Investigations

Sodium 134 mmol/L
Potassium 2.4 mmol/L
Magnesium 0.5 mmol/l
Bicarbonate 48 mmol/L
Creatinine 45 mmol/L

ABG:
pH 7.55
\( pCO_2 \) 7.9 kPa
Acid-base case 4

• Metabolic Alkalosis
Acid-base case 4

- Metabolic Alkalosis
- Volume contracted
  - so not primary MC excess or exogenous bicarbonate
Acid-base case 4

- Metabolic Alkalosis
- Volume contracted
  - so not primary MC excess or exogenous bicarbonate
- No significant GI H+ loss >> Renal H+ loss
Acid-base case 4

• Metabolic Alkalosis
• Volume contracted
  – so not primary MC excess or exogenous bicarbonate
• No significant GI H+ loss >> Renal H+ loss
• Diuretics?
• Distal renal tubule defect?
What’s in the urine?

- Urine K: high
- Urine Mg: high
- Urine Ca: low

- Diuretic screen: negative
Gitelman’s Syndrome

- Autosomal recessive
- Prevalence 1:40,000
- Volume contraction causes secondary hyperaldosteronism.
- Treatment: Spironolactone, KCl and Mg
Logical approach to acid-base cases

1. Look at the pH
   - If acidaemic: MUST be an acidosis
   - If alkalaemia: MUST be an alkalosis
   - If normal: could be: nothing wrong, compensation

2. Look for pattern of CO$_2$ and HCO$_3^-$:
   - Both low: met acidosis or chronic resp alk
   - Both high: met alkalosis chronic resp acid
   - Divergent: mixed disorder
Logical approach to acid-base cases

3. Metabolic Acidosis
   Anion Gap
   If high: hunt the exogenous acid
   If normal: GI HCO3 loss or RTA

4. Metabolic Alkalosis:
   ?Volume contracted:
   No: MC excess
   Yes: GI H+ loss or renal H+loss
Thank you

Dr Adam Feather
Prof Will Drake
Prof John Monson