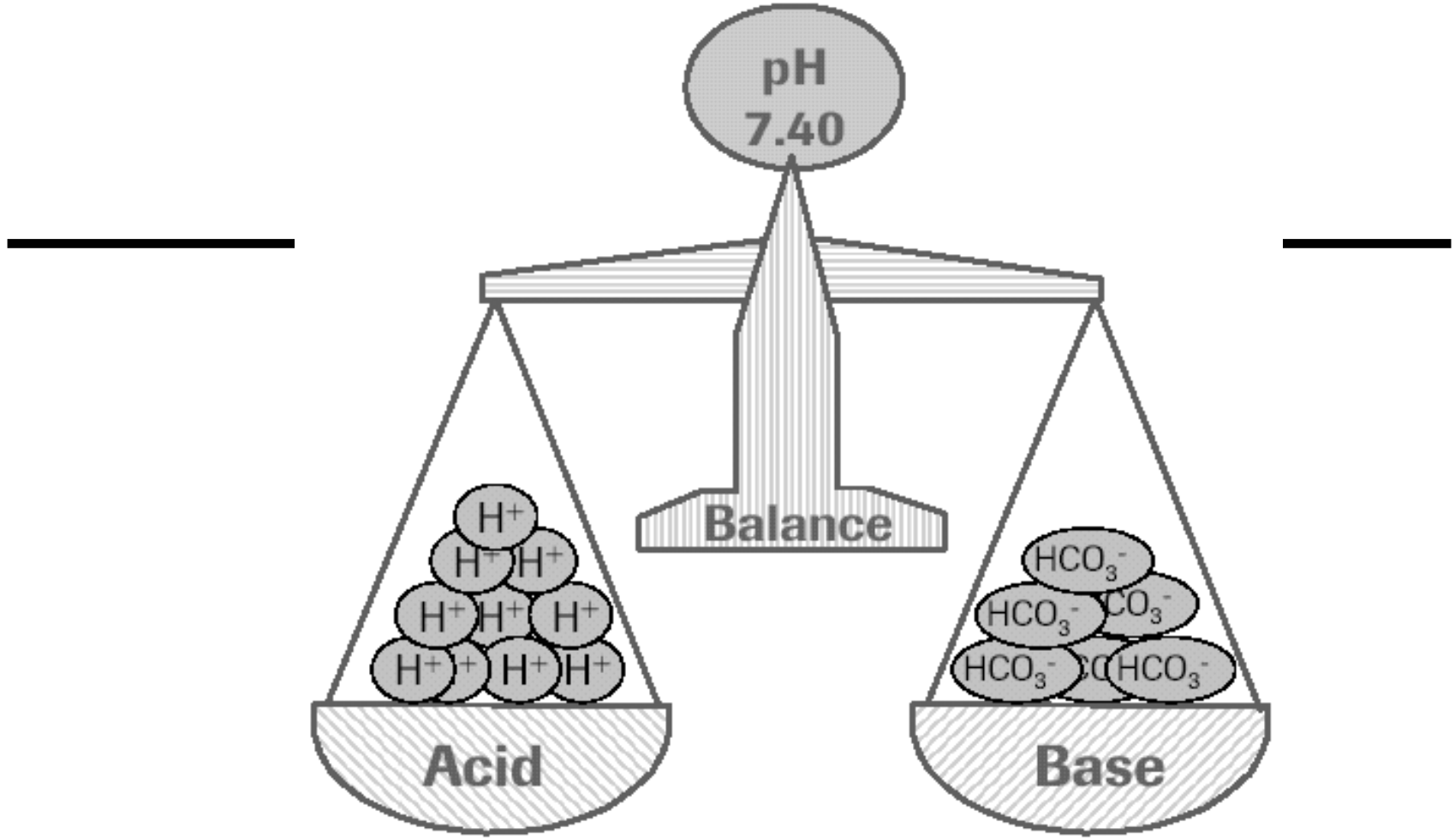
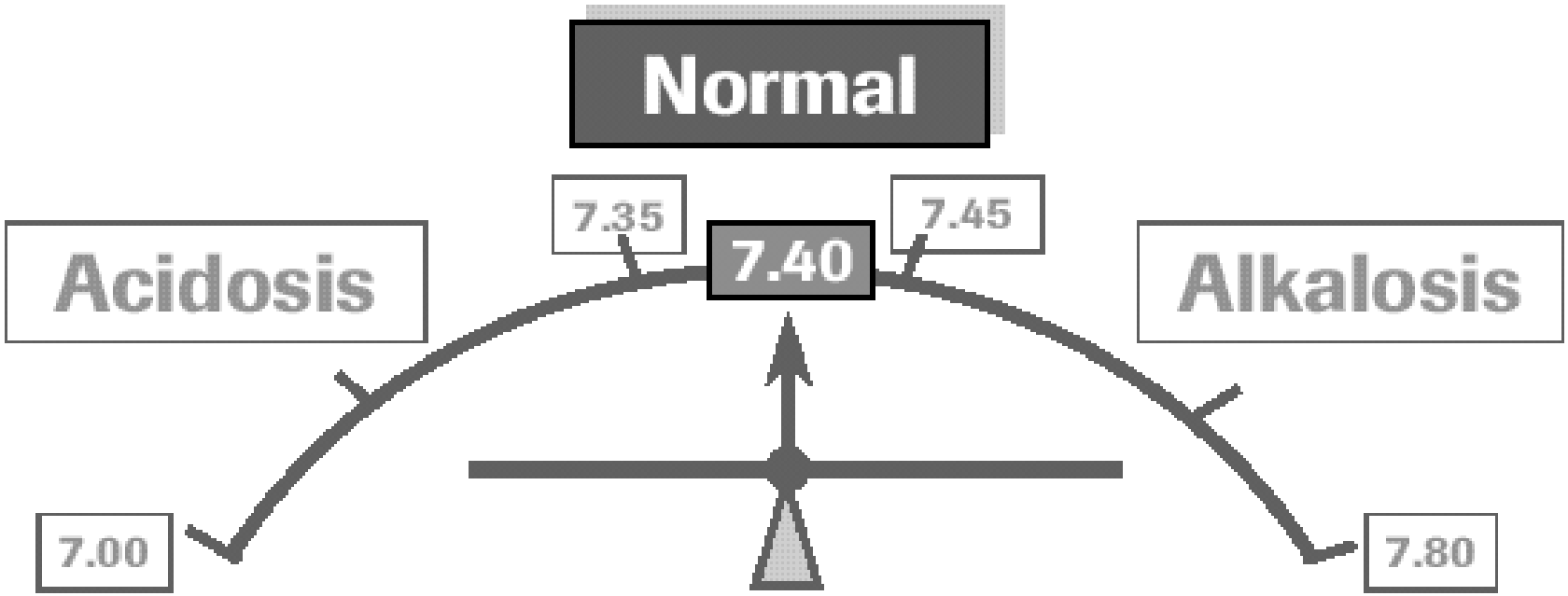
ABR: acid-base balance



Normal pH - very close ranges



Analyte	Unit	Reference intervale
pH		7.35 - 7.45
pCO_2	kPa	4.8 - 5.6
pO_2	kPa	10 - 13
actual HCO_3	mmol/l	22 - 26
standart HCO_3	mmol/l	22 - 26
BE (base exces)	mmol/l	± 2

pH - activity of hydrogen ions

- pH: 7.35-7.45

- Acidosis: pH < 7.35
  - „common“: 7.35 - 7.10
  - serious: 7.10 - 6.80
  - extremely: < 6.80 (life threatening)

- Alkalosis: > 7.45
  - serious: 7.45 - 7.70
  - extremely: > 7.70

Not serious acid-base disorders

- „Common“ acidosis: pH 7.35-7.10
  - „Physiological" situation
- Physiologic acids
  - Kenotic acids
  - Lactic acid
- There is no „common“ alkalosis
  - Alkalosis is always serious disorder
  - It often results from inadequate therapy of acidosis
- Normal pH
  - Aide-base disorder may be present

Correction of pH changes

- Buffers
  - To correct the influence of acids and bases
- Reaction of buffers
  - Immediately
- Compensation
  - With delay
  - Lungs and/or kidney

Buffers

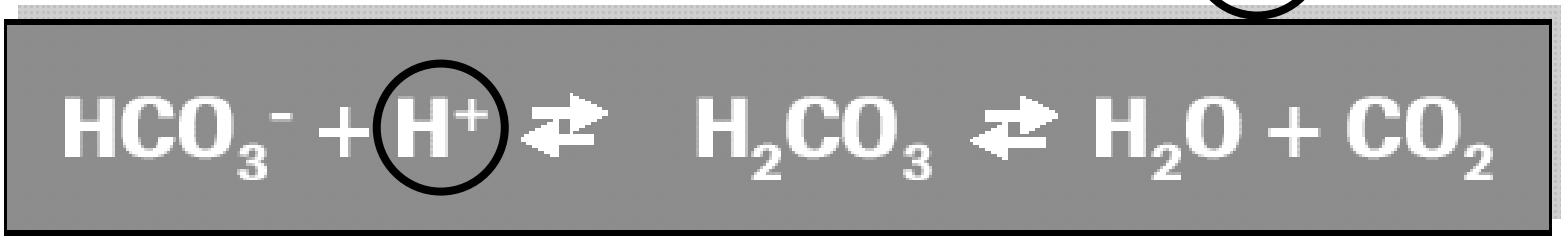
- Bicarbonate
  - Extracellular fluid (blood, interstitial fluid)
  - Cerebrospinal liquor - activity of the respiratory centre
- Haemoglobin
  - Intravasal fluid
- Phosphate
  - Intracellular fluid
  - Connection to the concentration of K^+ !
- Proteins
  - Both intra and extracellular fluid
  - Small capacity

Buffers

- Blood
  - Bicarbonate 53 %
  - Phosphate 5 %
  - Haemoglobin 35 %
  - Proteins 7 %
-

HCO_3^- a Hb system

- Bicarbonate
  - Concentration: 24 ± 2 mmol/l
  - Regulation of their blood level: kidney
  - Standard x actual HCO_3^-
- Haemoglobin
  - Similar capacity as HCO_3^-
  - HbO is stronger acid than Hb: it releases H^+
    - ★Tissues: HbO → Hb: binding of H^+
    - ★Lungs: Hb → HbO: release of H^+



Compensation of A-B disorders

- Respiratory A-B disorder
  - Renal compensation

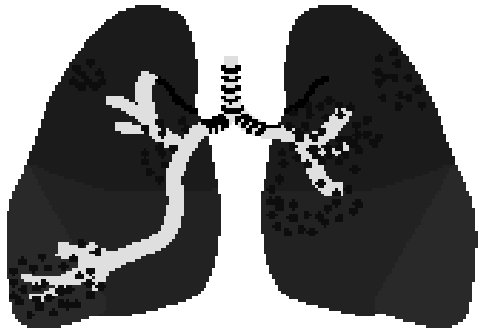
- „Metabolic“ A-B disorder
  - Lung and renal compensation

Respiratory compensation of A-B disorders
↑ or ↓ of ventilation

Acidosis

$$HCO_3^- + H^+ \rightleftharpoons H_2CO_3 \rightleftharpoons H_2O + CO_2$$

Excretion of CO_2 by lungs drives reaction to right.



Respiratory compensation of A-B disorders
↑ or ↓ of ventilation

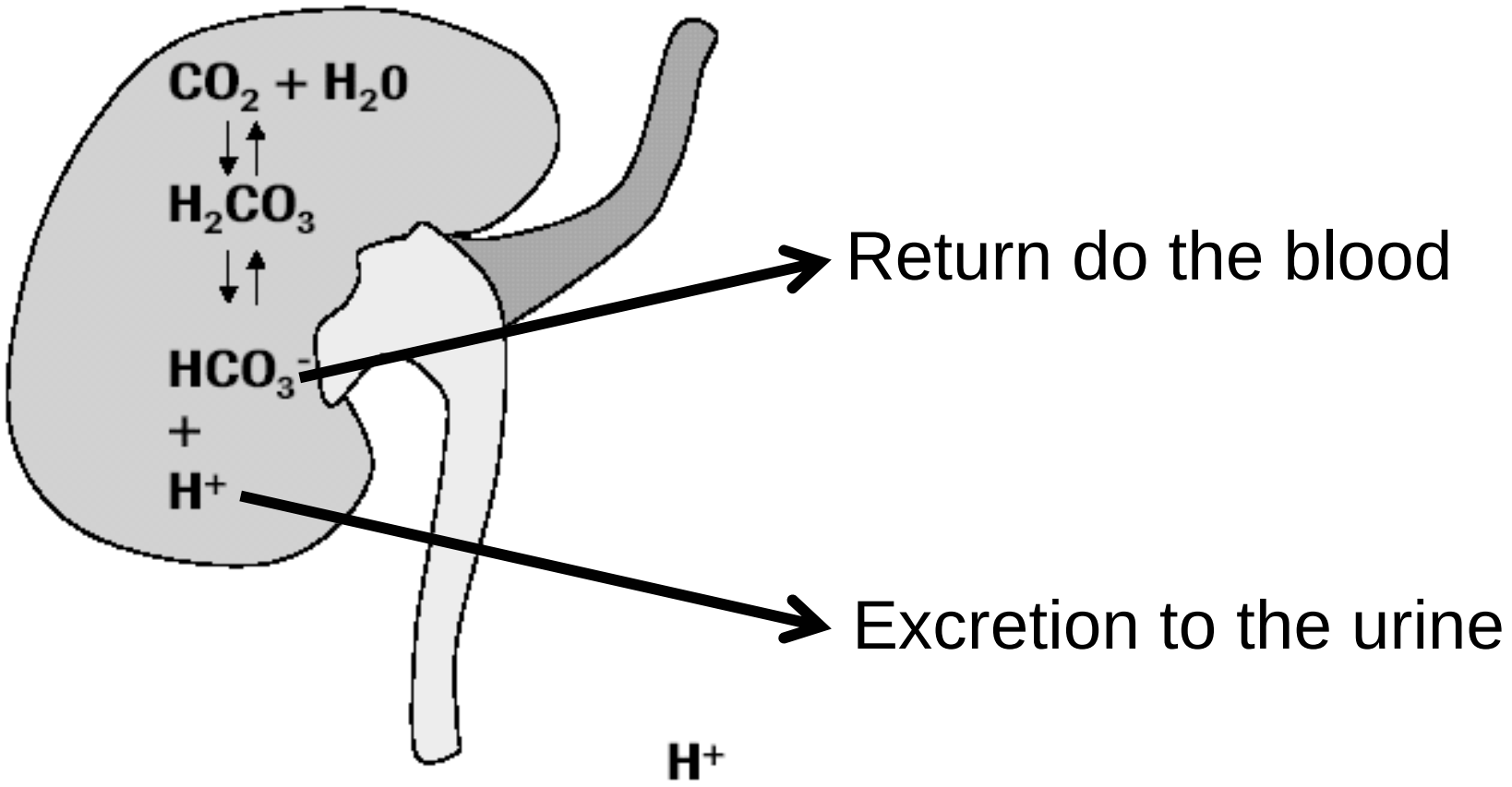
- Metabolic acidosis: hyperventilation
  - Stimulation of respiratory centre by low pH
  - Very effective mechanism
  - ↓ pCO_2, improved tissues saturation with O_2

- Metabolic alkalosis: hypoventilation = hypoxia !!
  - Inhibition of respiratory centre by elevated pH
  - Low effective mechanism
  - ↑ pCO_2, ↓ pO_2, hypoxia = hypoventilation is cancelled

Respiratory compensation of A-B disorders
↑ or ↓ of ventilation

- Respiratory compensation started immediately, but
  - Maximal compensation: 24 hours
  - Hyperventilation persists after adjustment of acidosis
    - ⋆Risk of respiratory alkalosis development

Renal compensation of A-B disorders



Renal compensation of A-B disorders

- Acidosis
  - Synthesis of HCO_3^-
  - Excretion of H^+ to urine
    - ★Ammonium ions (NH_4^+)
    - ★Phosphate ions ($H_2PO_4^-$)
- Alkalosis:
  - Excretion of HCO_3^- to the urine
  - Inhibition of H^+ elimination
    - ★Stop of NH_4 synthesis
    - ★HPO_4^{2-} synthesis is started

Renal compensation of A-B disorders

- Renal compensation starts during 24 hours
  - It is complete is after 1 week
  - When is acidosis or alkalosis removed (therapy), compensation continues several days
    - ⋆Risk of reverse A-B disorder !

Acid-base disorders

- Simple disorders
  1. Metabolic acidosis
  2. Metabolic alkalosis
  3. Respiratory acidosis
  4. Respiratory alkalosis

- Combined acid-base disorders
  - Result of compensation mechanisms
  - Primary combined disorders

Metabolic acidosis

- Laboratory diagnosis:
  - $\downarrow$ pH
  - $\downarrow$ HCO_3^-
  - $\leftrightarrow$ pCO_2 (acute), $\downarrow$ (lung compensation)

- Causes:

a) Without HCO_3^- loss

★ $\uparrow$ acids

b) Due to loss of HCO_3^-

Acidosis without HCO_3^- loss

- ↑ production of acids
  - Kenotic acids
    - ★Starvation, decom. DM, high grade fever
  - Others acids
    - ★Intoxications
      - ➔Salicylate, ethylene glycol (oxalic acid), methanol (formate)
- Acid retention
  - Acute renal failure, chronic renal failure

Acidosis without HCO_3^- loss
Lactic acidosis

- Type A (hypoxic): hypoxia from any causes
  - Respiratory insufficiency, shock
  - Anaemia (Hb < 70 g/l), carbon monoxide poisoning, extreme muscular activity
  - Blood stagnation

- Type B (insufficient utilization of lactic acid)
  - Hepatic failure
  - Biguanide poisoning
  - Sepsis

Acidosis due to bicarbonate loss

- Real bicarbonates loss
  - Diarrhoea
  - Pancreatic fistula

- Decline of bicarbonates: Hyperchloremic acidosis
  - ↑ chloride intake
    - ★KCl, NaCl, NH_4Cl

Therapy of the metabolic acidosis

- $NaHCO_3$
  - How much ?

- Calculation
  - mmol HCO_3 = BE x 0.3 x weight (kg)

Therapy of the metabolic acidosis

The rules for therapy of met. ac.

- Therapy must be causal (if possible) !!!
- Maximal dose of bicarbonate
  - 1/3 - 1/2 of the calculated dose
- HCO_3^- is indicated only when
  - Causal therapy is not possible
  - pH < 7,1
- Chronic met. ac.: treatment with caution
  - Compensation with both hyperventilation and kidney
    - ★Risk of alkalosis after therapy

Therapy of MAC with HCO_3^- :YES or NO ?

- Ketoacidosis: No
  - Starvation - nutrition
  - Decom. DM - insulin
  - Intoxication (ethylene glycol, methanol)
    - ★Dialysis

- Renal failure: No
  - Haemodialysis

Therapy of MAC with HCO_3^- :YES or NO ?

- Lactic hypoxic acidosis type A: NO !!!
  - Oxygen therapy
- Type B
  - Hepatic failure, sepsis: specific therapy
  - Biguanide poisoning: Yes, but dialysis and/or hemoperfusion is necessary

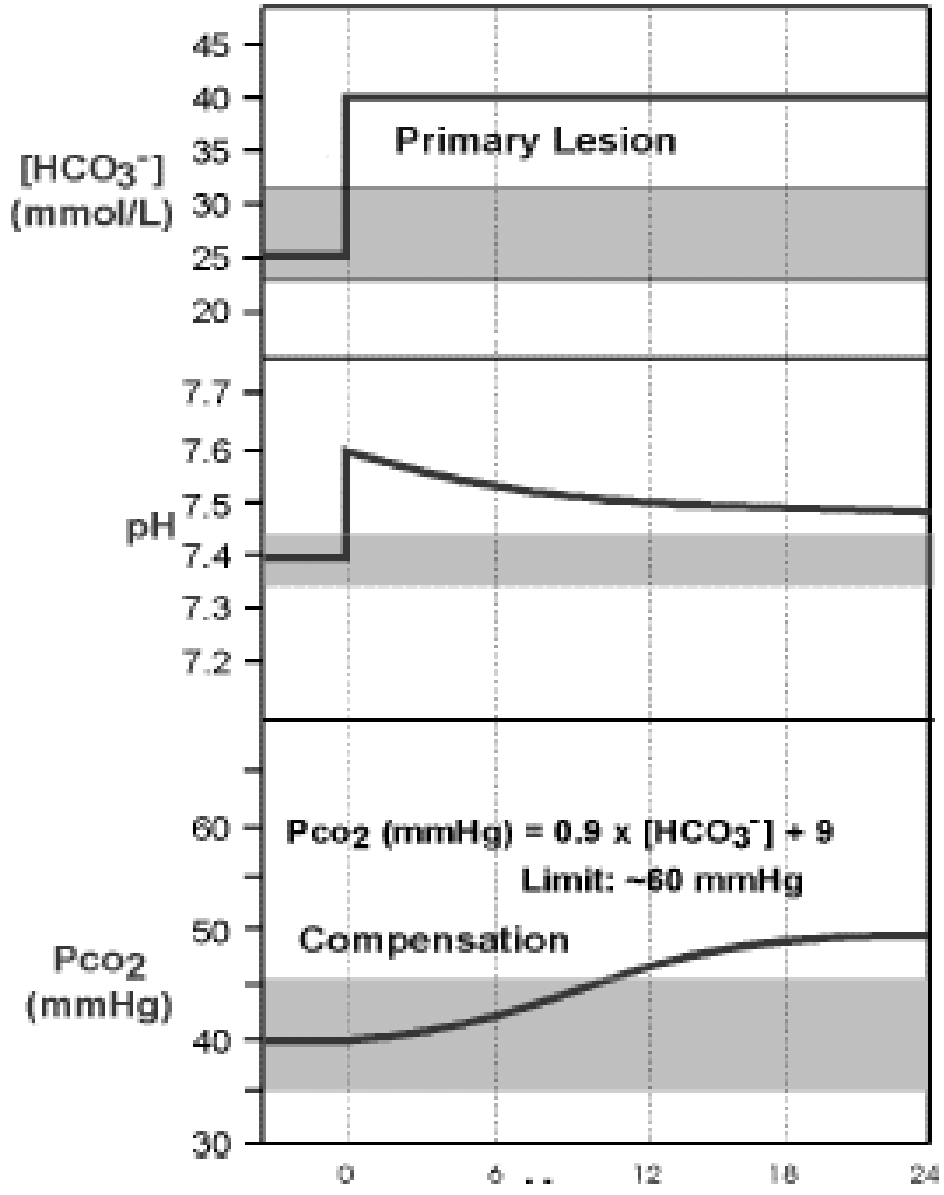
- Loss of bicarbonates
  - Diarrhoea, pancreatic fistula: Yes
  - Hyperchloremic acidosis: No
    - ★Thiazid diuretics

Metabolic alkalosis

- Dg:
  - $\uparrow$ pH
  - $\uparrow$ HCO_3
  - $\leftrightarrow$ pCO_2 (acute), $\uparrow$ (lung compensation)

- Types of MAL:
  - Responding for treatment with chlorides
    - ★ MAL due to loss of Cl
  - Not responding for treatment with chlorides

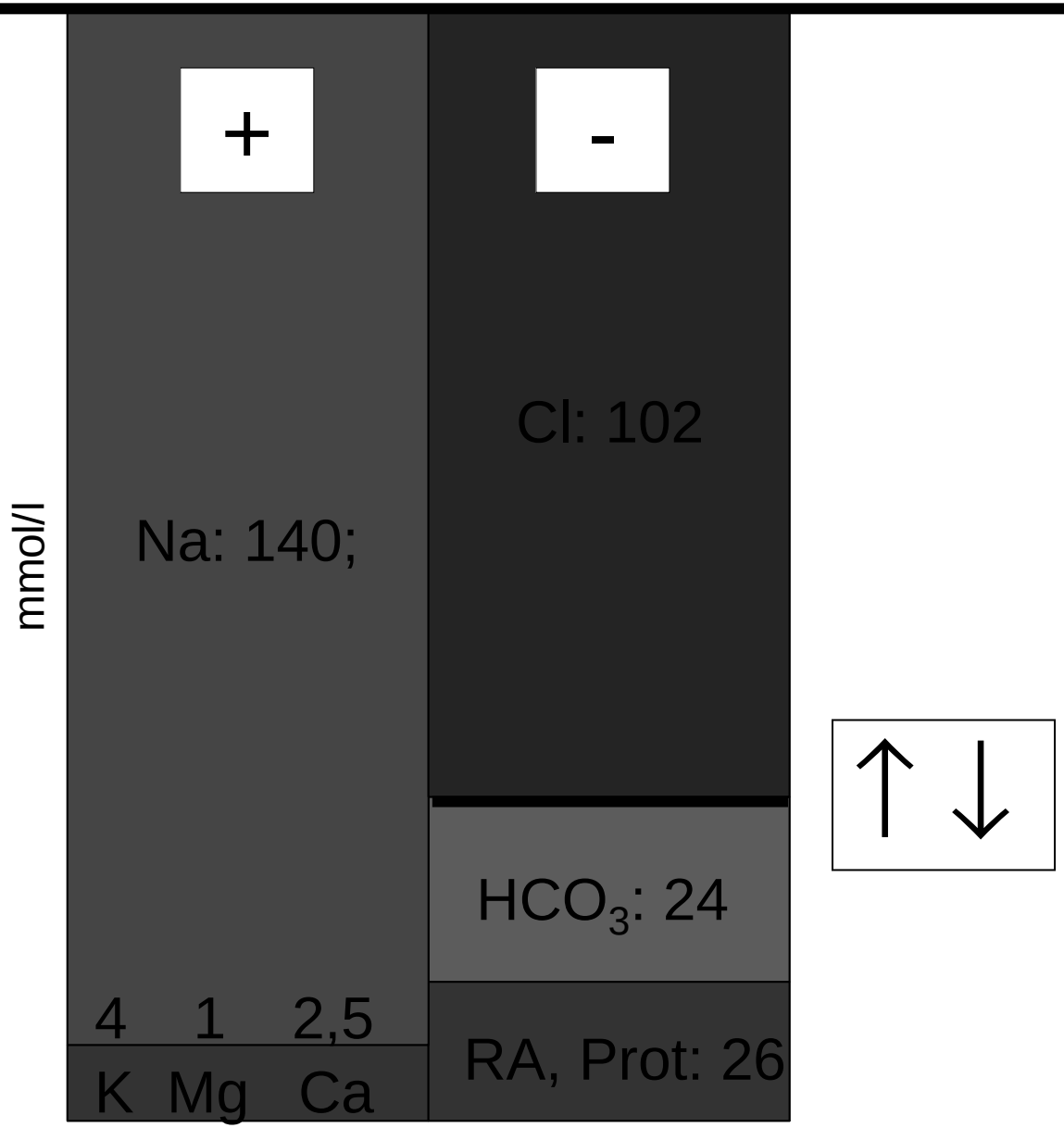
Metabolic alkalosis



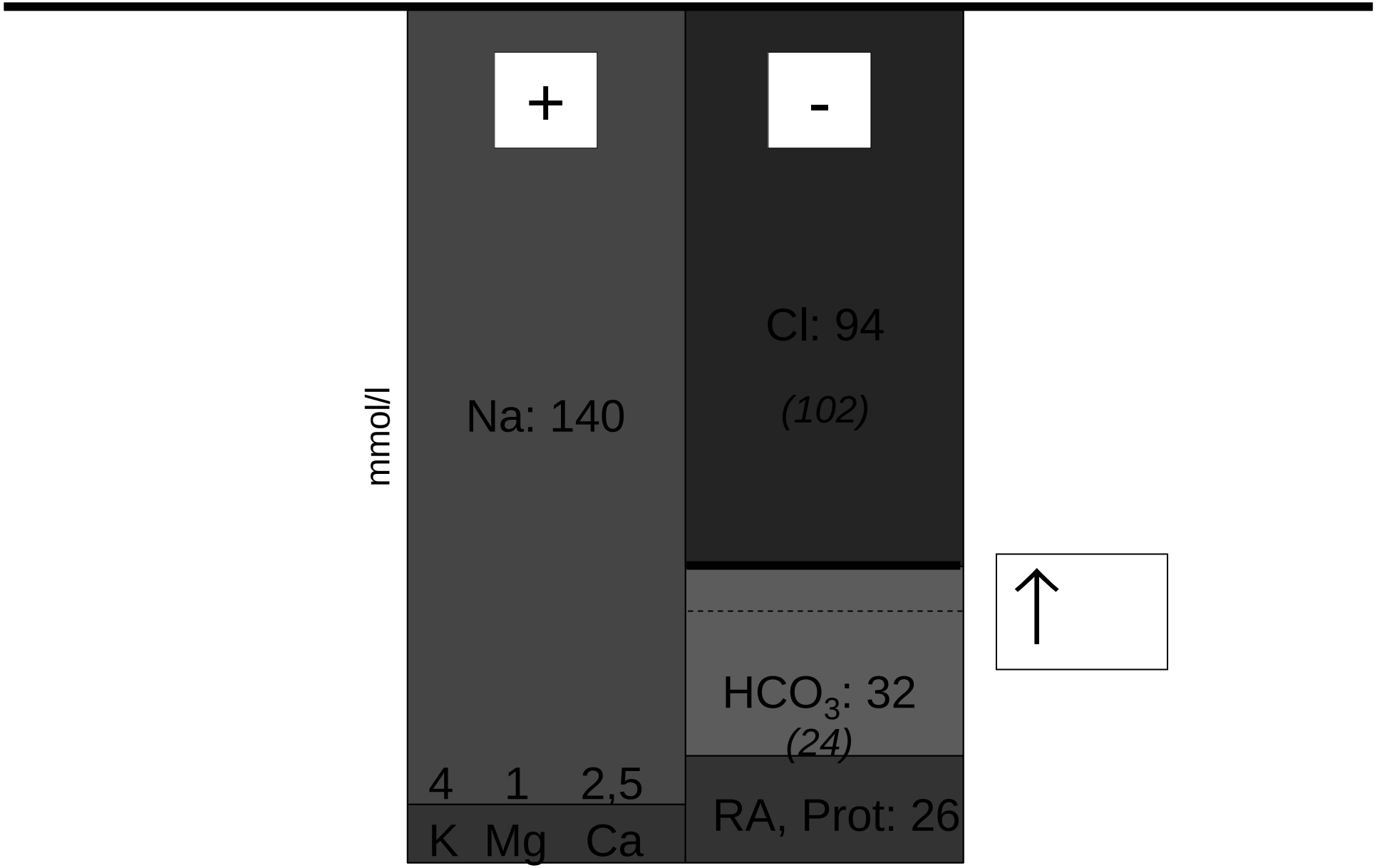
MAL due to loss of Cl

- Vomiting
- Drainage of gastric juice
- Overdosing of diuretics (thiazides)

Concentration of the ions in the extracel. fluid



Lack of chlorides = alkalosis



MAL due to lack of Cl: therapy

- Cl^-
  - NaCl, KCl, NH_4Cl, arginin hydrochlorid
- How much of Cl^- ?
  - BE x 0.3 x weignt (kg)
  - Deficite of Cl^- x 0.3 x weight (kg)

- The rules for therapy of met. alkalosis
  - Therapy is always indicated
  - The full calculated dose of Cl^- should be given
- Alkalosis is more dangerous than acidosis!

MAL not responding for treatment with Cl^-

- Hyperaldosteronism
- Long-term therapy with glukocorticoides
- Iatrogenic
  - ↑ supplementation of HCO_3^-

MAL not responding for treatment with Cl^-:

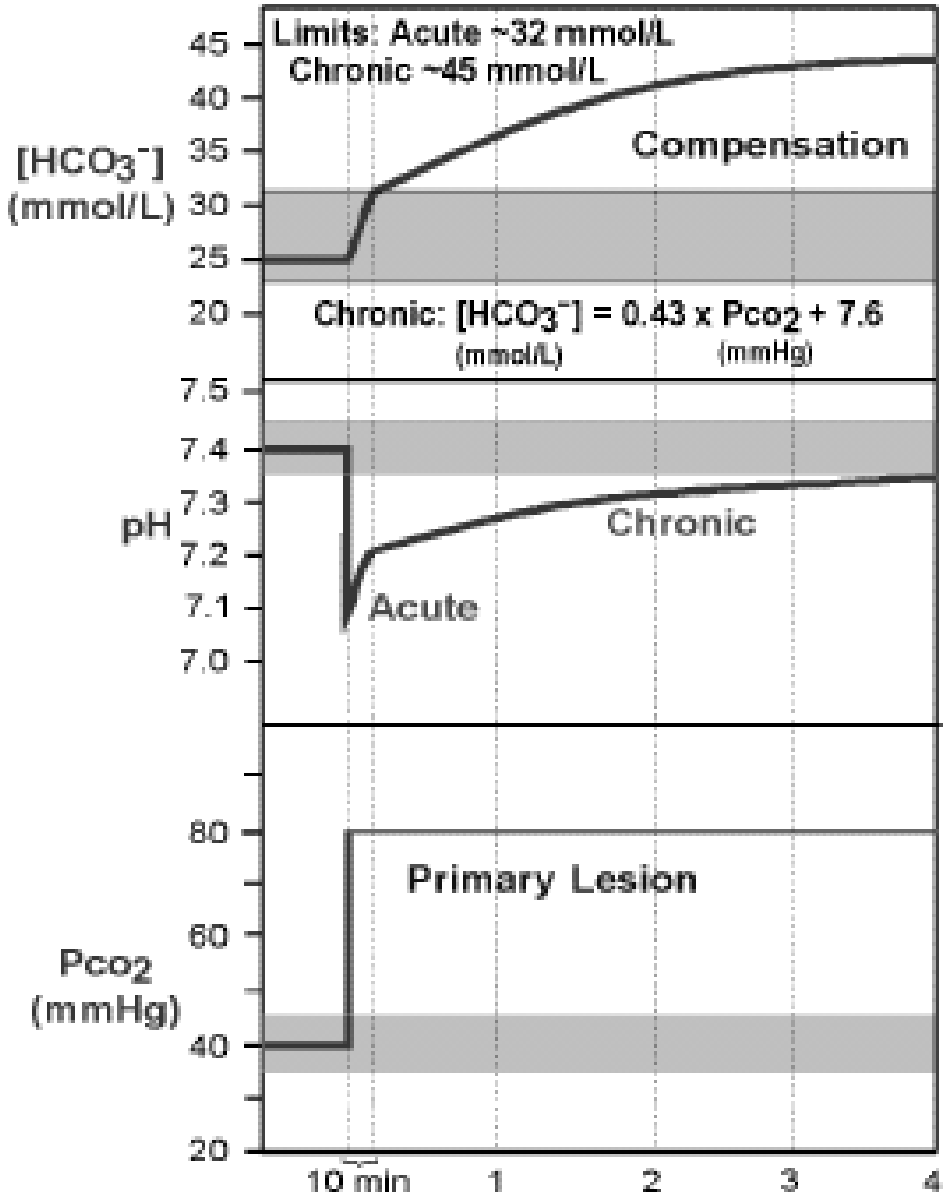
- Therapy must be causal
- Hypokalemia - KCl
- Live- threatening MAL - Hemodialysis

Respiratory acidosis (RAC)

- It is characterized by retention of CO_2
- Dg:
  - $\downarrow$ pH
  - $\uparrow$ pCO_2
  - $\leftrightarrow$ HCO_3, then $\uparrow$ (kidney compensation)

- Cause of RAC: retention CO_2
  - Central
  - Ventilatory
  - Cardiac

Respiratory acidosis



Deviation of pH may be greatly reduced by the process of compensation

Respiratory acidosis (RAC)

- Central (depression of respiratory centre)
  - Drug induced - sedatives, narcotics
  - Lesions of resp. centre - tumour, trauma, ...

Respiratory acidosis (RAC)

- Ventilatory
  - Neuromuscular (myastenia gravis, botulism)
  - Muscles (myositis, muscular dystrophy)
  - Thorax (pneumothorax)
  - Respiratory tract (asthma, bronchostenosis, tumour)
  - Lung parenchyma (lung oedema, ARDS, pneumonia)

Respiratory acidosis (RAC)

- Cardiac
  - Low minute volume of cardiac output

Respiratory acidosis: Therapy

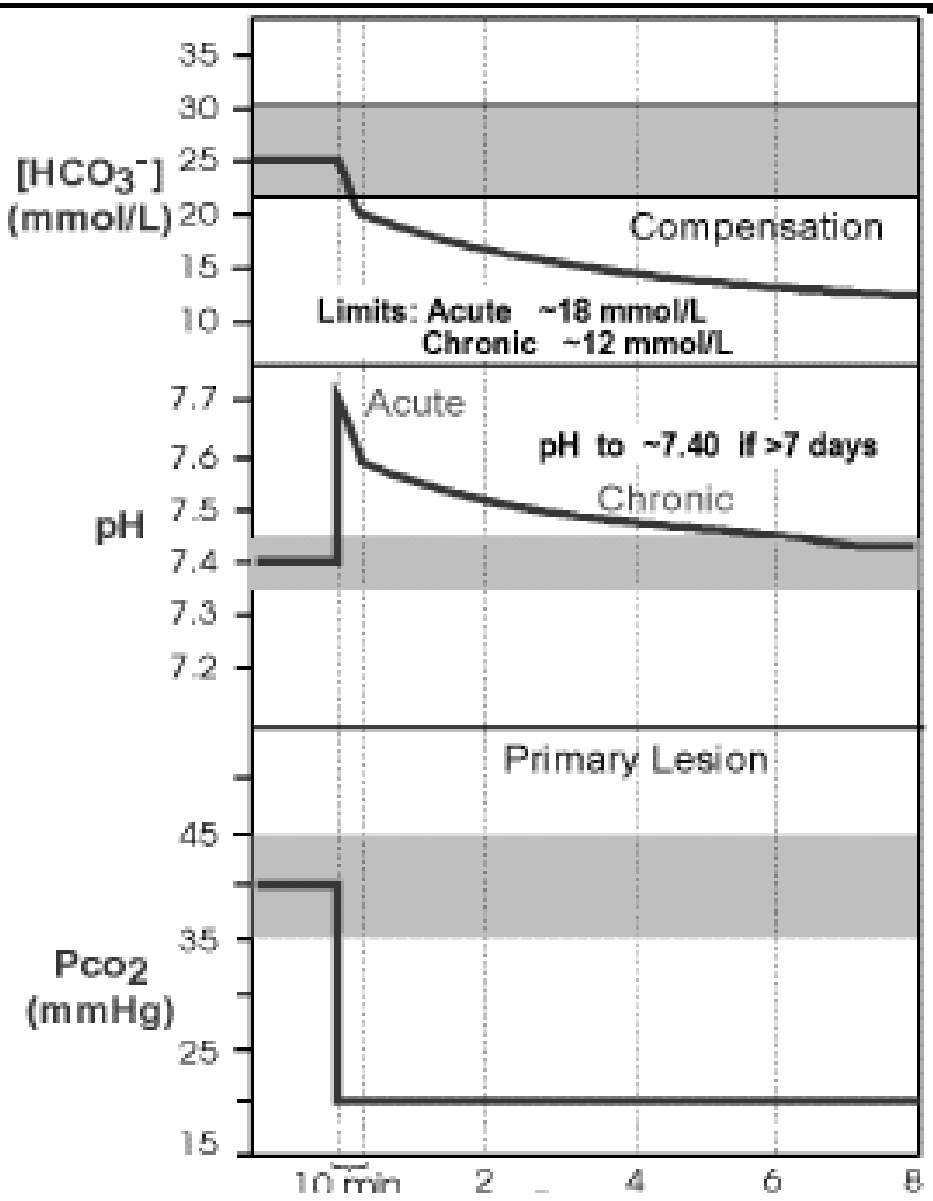
- Therapy must be causal !!
- Hypoxia is more serious problem then acidosis !!!
- Improvement of ventilation, sometime oxygen
- In the life threatening RAC
  - Mechanical ventilation
- Bicarbonate is contraindicated !!!

- Oxygen must be done with caution !
  - Hypoxia stimulated respiratory centre
    - ★High O_2 doses can stop respiration

Respiratory alkalosis (RAL)

- Stimulation of the respiratory center
- Dg:
  - ↑ pH
  - ↓ pCO_2
  - ↔ HCO_3, then ↓ (kidney compenzation)

Respiratory alkalosis



Respiratory alkalosis (RAL)

- Causes of RAL
  - Hyperventilatory syndrom
    - Anxiety, hysteria
  - Lesions of the CNS
    - Encephalitis, meningitis, tumours, trauma

Respiratory alkalosis (RAL): Therapy

- Depression of the respiratory center
- Hyperventilatory syndrom
  - Sedatives
- Life threatening RAL
  - Mechanical ventilation

Combined A-B disorders

- Primary combined A-B disorders

- Result of the compensation mechanisms
  - Metabolic acidosis is compensated by respiratory alkalosis
  - Metabolic alkalosis is compensated by respiratory acidosis
  - Respiratory acidosis is compensated by metabolic alkalosis
  - Respiratory alkalosis is compensated by metabolic acidosis

How to recognized combined A-B disorders ?

- Respiratory component can be found easy
  - pCO_2 is changed

- Metabolic components may be sometimes difficult to detect, as both acidosis and alkalosis may be present and they result to the relatively normal laboratory values (pH, HCO_3, pCO_2, pO_2):
  - Concentration of Cl^- , K^+, Na^+ must be measured !
  - Some calculation may be useful

How to recognized combined A-B disorders ?

- An interpretation of the blood´s A-B status must take into account the electrolyte status
- ***Cl and K deserve special attention!***
- Changes in Cl^- conc. are followed by the changes in A-B status
  - ↑ of Cl^- results in ↓ of HCO_3^- and it is followed by metabolic acidosis (hyperchloremic acidosis)
  - ↓ of Cl^- results in ↑ of HCO_3^- and it is followed by metabolic alkalosis (hypochloremic alkalosis)

Formulas that can contribute to the detection of the combined disorders:

- Buffer Base = $Na^+ + K^+ - Cl^-$
  - Normal result: 42 mmol/l
  - ↑ = metabolic alkalosis is probably present

Formulas that can contribute to the detection of the combined disorders:

- Anion gap = $(Na^+ + K^+) - (Cl^- + HCO_3^-)$
- Normal result = 18 mmol/l)
- ↑ = metabolic acidosis is probably present (↑concentration of organics anions)
  - Lactate, kenotic acids, multiple acid radicals

How to recognized combined A-B disorders ?

- Normal pH do not exclude A-B disorders !

- What we need for interpretation of A-B status ?
  - pH, HCO_3^-, pCO_2, pO_2
  - Na, K, Cl
  - **Patients´s history and clinical examination!**

Physiologic values of AB balance

Parameter	Unit	Reference ranges	Critical values
pH		7.35 - 7.45	< 7.1; > 7.6
pCO_2	kPa	4.8 - 5.6	< 3.3; > 8.1
pO_2	kPa	10 - 13	< 6.7
akt.-HCO_3	mmol/l	22 - 26	< 5; > 55
stan.-HCO_3	mmol/l	22 - 26	< 5; > 55
BE	mmol/l	$\pm$ 2	

Laboratory diagnostic of A-B disorders

		HCO_3	pH	pCO_2
Metabol. acidosis	Acute	↓↓	↓↓	N
	Chron.	↓	↓	↓
Metabol. alkalosis	Acute	↑↑	↑↑	N
	Chron.	↑	↑	↑
Respir. acidosis	Acute	N,↑	↓↓	↑↑
	Chron.	↑	↓	↑↑
Respir. alkalosis	Acute	N, ↓	↑↑	↓↓
	Chron.	↓	↑	↓↓