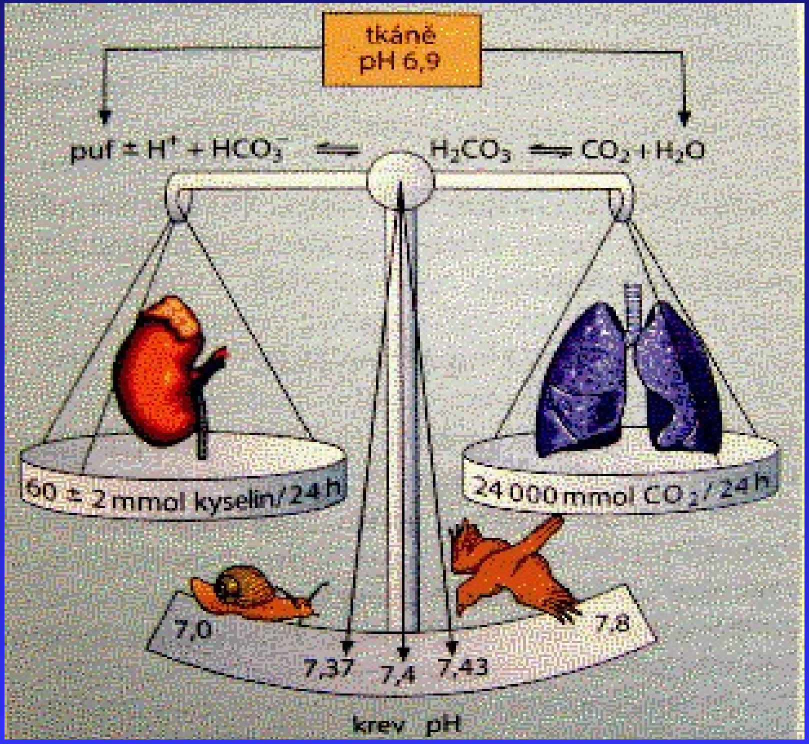
Fluid, electrolyte and acide-base disturbances in surgery (not only)



L.Dadak
Dept. of Anesthesia and Intensive Care
St. Ann's University Hospital

Homeostasis

- tendency to keep stable

- isovolemia
- H+ = pH, pCO_2,
- Glc, ions

- isohydria, isoionia, isoosmia

Laboratory

- Never completely trust the laboratory
  - errors with blood sample
- Will result change my decision?

Never completely trust the laboratory

Quick	<0.10		(0.70 - 1.34)	<-( )	repeated
aPTT	>150	s	(20.0 - 40.0)	<=( )	repeated
Fibrinogen	4.50	g/l	(1.80 - 4.00)	( )->	
Antitrombin III	32	%	(80 - 120)	<-( )	

- - - - - - - - - - - - same patient, 30 min later - - - - - - - - - - - - - -

Quick	0.55		(0.70 - 1.34)	<-( )
aPTT	44.7	s	(20.0 - 40.0)	( )->
Aptt ratio	1.49			
Fibrinogen	5.40	g/l	(1.80 - 4.00)	( )->
INR	1.59		(0.85 - 1.38)	( )->
Antitrombin III	61	%	(80 - 120)	<-( )

Blood for analysis

- arterial
- capillary
- venous
  - peripheral
  - central
  - mixed venous (v.cava, a.pulmonalis)

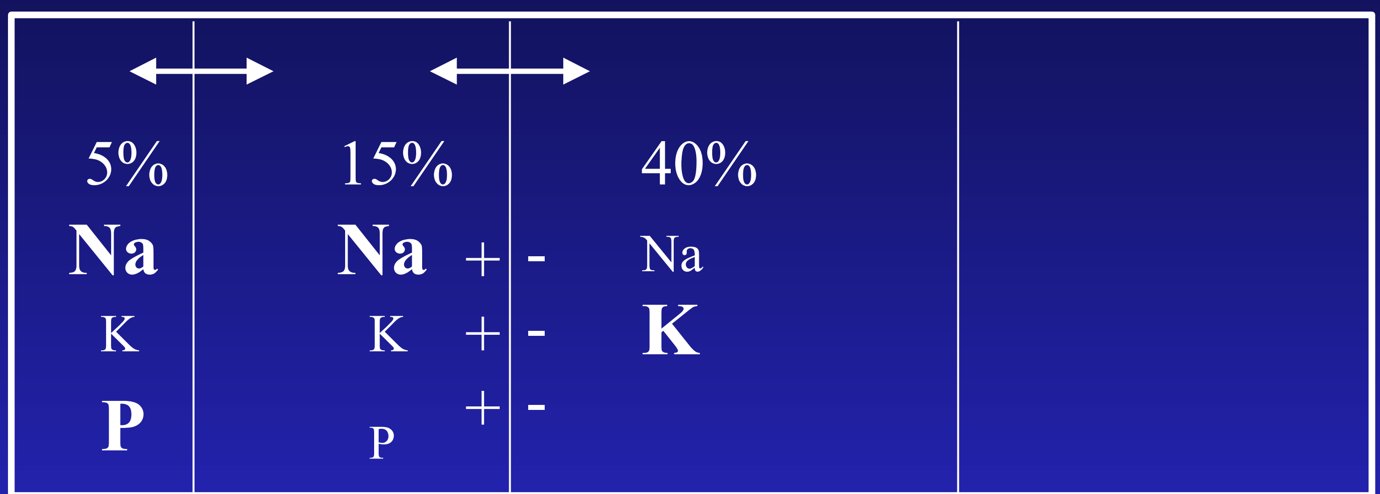
Body Fluid Compartments

Total Body Water (TBW): 50-70% of total body wt.

- Avg. is greater for males.
- Decreases with age. Highest in newborn, 75-80%. By first year of life TBW ~ 65%.
- Most in muscle, less in fat.
- TBW= ECF + ICF
- ICF ~ 2/3 & ECF ~ 1/3
- ECF = Intravascular (1/3) + Interstitial (2/3)

Water - compartments:

ECF = IVF + ISF ICF



ICF (mEq/L)	ECF (mEq/L)
Cations	
K+ (150-154)	Na+(142)
Na+ (6-10)	Ca+2 (5)
Mg+2 (40)	K+ (4-5)
	Mg+2 (3)
Anions	
Organic PO4-3 (100-106)	Cl-(103-105)
protein (40-60)	HCO3- (24-27)
SO4-2 (17)	protein (15)
HCO3- (10-13)	PO4-3 (3-5), SO4-2 (4)
organic acids (4)	Organic acids (2-5)

Electrolyte Physiology

- Primary intravascular/ECF cation is Na^+. Very small contribution of K^+, Ca^{2+}, and Mg^{2+}.
- Primary intravascular/ECF anion is Cl^-. Smaller contribution from HCO_3^-, SO_4^{2-} & PO_4^{3-}, organic acids, and protein.

- Primary ICF cation is K^+. Smaller contribution from Mg^{2+} & Na^+.
- Number of intravasc anions not routinely detected.

Intra Vascular Fluid

- Treatable volume

Provides:

- Nutrition
- Oxygenation
- Waste removal
- Temperature
- Alkalinity

Priorities

1. fluid volume and perfusion deficits
2. correction of pH
3. K, Ca, Mg
4. Na, Cl

IV Fluid/Electrolyte Therapy

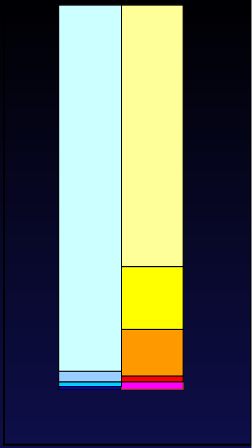
Three key concepts in consideration of fluid and electrolyte management:

- cell membrane permeability
- osmolarity
- electroneutrality

Cell membrane permeability refers to the ability of a cell membrane to allow certain substances such as water and urea to pass freely, while charged ions such as sodium cannot cross the membrane and are trapped on one side of it.

Osmolarity

- Osmolarity is a property of particles in solution. If a substance can dissociate in solution, it may contribute more than one equivalent to the osmolarity of the solution. For instance, NaCl will dissociate into two osmotically active ions: Na and Cl. One millimolar NaCl yields a 2 milliosmolar solution.



Electroneutrality

- in every solution
- sum of [mval/l] cations is equal to sum of anions

- Na+, K+, Mg++, Ca++ ...
- Cl-, HCO3-, PO4--, proteins-

Osmolarity, osmolality

- Each particle present in the water binds number molecules of water.

Serum osmolarity is **measured** directly by determining the **freezing** point of serum.

normal 275 .. 295 mOsm/l

Calculated osmolarity = 2 * Na + Glc + Urea [mOsm/l]

2* 140 + 5 + 3

Gap > 10 mOsm/l ... another solute (lactate, ethanol)

Gap > 50 mOsm/l ... often fatal

Osmolality [mmol/kg of water]

Water

- 55% - 60%, new born 80% of body weight

Table 2-1
Water Exchange (60- to 80-kg Man)

Routes	*Average Daily Volume (mL)*	*Minimal, (mL)*	*Maximal, (mL)*
H_2O gain:			
Sensible:			
Oral fluids	800–1500	0	1500/h
Solid foods	500–700	0	1500
Insensible:			
Water of oxidation	250	125	800
Water of solution	0	0	500
H_2O loss:			
Sensible:			
Urine	800–1500	300	1400/h
Intestinal	0–250	0	2500/h
Sweat	0	0	4000/h
Insensible:			
Lungs and skin	600	600	1500

Table 2 Daily Electrolyte Requirements

	DAILY REQUIREMENT	FOR 70-KG ADULT	FOR 10-KG CHILD
Sodium	1-2 meq/kg	70-140 meq/day	10-20 meq/day
Potassium	0.5-1.0 meq/kg	35-70 meq/day	5-10 meq/day
Calcium	0.2-0.3 meq/kg	1.4-2.1 meq/day	2.0-3.0 meq/day
Magnesium	0.35-0.45 meq/kg	24.5-31.5 meq/day	3.5-4.5 meq/day
Chloride	equal to sodium	equal to sodium	equal to sodium
Bicarbonate/Acetate	use with chloride to balance cations and help pH	use with chloride to balance cations and help pH	use with chloride to balance cations and help pH

Basic Needs (Adult)

- Basic need 2 ml/kg/h
- Current losses
  - 1°C fever = 500ml/d
  - sweating
  - diarrhea ... water with ions [mmol/l]

	Sodium	Potassium	Chloride	Bicarbonate
Saliva	10–60	10–20	15–40	30–15
Stomach	40–100	5–15	15–20	—
Bile	130–140	4–6	95–105	30–40
Pancreas	130–140	4–6	40–60	80–100
Small intestine	130–140	4–6	40–60	80–100
Colon	80–140	25–45	80–100	30–50
Sweat	40–50	5–10	45–60	—

Types of IV Fluid

- Crystalloid
- Colloid

Crystalloid:

- Balanced salt/electrolyte solution; forms a true solution and is capable of passing through semipermeable membranes. May be isotonic, hypertonic, or hypotonic.
- Normal Saline (0.9% NaCl), Lactated Ringer’s, Hypertonic saline (3, 5, & 7.5%), Ringer’s solution.
- However, hypertonic solutions are considered plasma expanders as they act to increase the circulatory volume via movement of intracellular and interstitial water into the intravascular space

Colloid:

- Colloid: High-molecular-weight solutions, draw fluid into intravascular compartment via oncotic pressure (pressure exerted by plasma proteins not capable of passing through membranes on capillary walls). Plasma expanders, as they are composed of macromolecules, and are retained in the intravascular space.
- HAES, Gelatina (Dextran);
- Albumin, Plasma

"Free H2O solutions:"

- Free H2O solutions: provide water that is not bound by macromolecules or organelles, free to pass through.
- D5W (5% dextrose in water), D10W, D20W, D50W, and Dextrose/crystalloid mixes.

IVF can supply 3 things

- fluid,
- electrolytes,
- calories (150 ml/h D5W)

The most common uses for IVF:

- Acutely expand intravascular volume in hypovolemic states
- Correct electrolyte imbalances
- Maintain basal hydration

infusion:

- Ringer's lactate solution
- NS = Normal Saline = NaCl 0,9%

Normal Saline (0.9% NaCl):

- Isotonic salt water.
  154 mEq/L Na+; 154 mEq/L Cl-; 308mOsm/L.
- (Cheapest), commonly used crystalloid.
- High [Cl-] above the normal serum 103 mEq/L imposes on the kidneys an appreciable load of excess Cl- that cannot be rapidly excreted. A **dilutional acidosis** may develop by reducing base bicarb relative to carbonic acid. Thus exist the risk of hyperchloremic acidosis.
- Only solution that may be administered with blood products.
- Does not provide free water or calories.

Lactated Ringer's solution

- isotonic, beginning of volume resuscitation

Ingredients:

* 130 mEq of sodium ion.
* 109 mEq of chloride ion.
* 28 mEq of lactate.
* 4 mEq of potassium ion.
* 3 mEq of calcium ion.

Lactate is converted readily to bicarb by the liver. Has minimal effects on normal body fluid composition and pH. More closely resembles

Volume

Volume deficits are best estimated by acute changes in weight. Less than 5% loss is very difficult to detect clinically and loss of 15+% will be associated with severe circulatory compromise.

- Mild deficit represents a loss of ~ 4% body wt.
- Moderate deficit --- a loss of ~ 6-8% body wt.
- Severe deficit --- a loss of ~ >10% body wt.

Volume deficit may be a pure water deficit or combined water and electrolyte deficit.

Resuscitative IV Fluids

Principle of trauma & surgery: Crystalloids; isotonic balanced salt solutions (Ringer-Lactate).

Amount given based upon body wt, clinical picture, and vital signs = shock.

Generally a bolus of 500-2000cc is given depending on the above, then rates are run at 1.5-2x maintenance or 10-20cc/kg/d on top of maintenance. Continuous clinical reassessment of vitals and response to fluids already given is required for ongoing IVF therapy.

Monitoring endpoints for IVF therapy

Endpoint should be maintenance or reestablishment of homeostasis.

- In order to reestablish homeostasis in a pt, IVF therapy must not only provide a **balance of water** and

electrolytes, but must ensure adequate **oxygen delivery** to all organs and renal perfusion as evidenced by urine output.

- Endpoints: normalization of VS, UO>0.5ml/kg/hr (1ml/kg/hr for a child) and restoration of normal mental status and lack of clinical signs of deficit.

Hypovolemia

- deficit of water
- estimated from
  - weight loss
  - thirst
  - physical signs (soft eyes, tachycardia, hypotension, oliguria, organ dysfunction – brain)
- hypo, iso, hypertonic

- Treatment: add water (crystaloid, coloid)

Hypervolemia

- hypotonic – excess of water (no ions e.g. 5% Glc)
- isotonic – anuria + intake crystaloids
- hypertonic – intake of concentrated solutions, loss of hypoosmolar fluid. / rare/

Ions in the body

- Sodium Na^{+}
- Potassium K^{+}
- Calcium Ca^{++}
- Magnesium Mg^{++}
- Phosphorus PO_4^{-}
- Chloride Cl^{-}

- - - - - - - - - - -

- Glucose Glc

Sodium Na+

• extracellular fluid	140 mmol/l
• intracellular fluid	10 mmol/l

- Hyponatremia
- Hypernatremia

Hyponatremia Na+ in serum < 120 mmol/l

- usually due to hemodilution by too much water
- sodium loss
  - vomiting
  - diarrhea
  - sweating,
  - renal / CNS disorders, diuretics
  - third space sequestration (burns, pancreatitis, peritonitis)
- factitous (hyperglycemia, hyperlipidemia, manitol) - osmolality normal / increased

Hyponatremia - symptoms

- Fatique
- Apathy, coma, **change in mental status**
- Headache
- Muscle **cramps**, weakness
- Anorexia, nausea, vomiting,

- Mild to moderate hyponatremia is usually asymptomatic.

Treatment of hyponatremia

- stable pat. - water restriction (less 1l/d)
- severe, acute hyponatremia (duration < 48 h) , symptomatic pt. with brain edema
  3% NaCl i.v.

- Rate of correction should not exceed 0.5-1 mEq/L/h, with a total increase not to exceed 12 mEq/L/d
- Risk of rapid treatment - demyelinisation

Hypernatremia

- inadequate water intake
- excessive loss of water
  - diarrhea
  - vomiting
  - hyperpyrexia
  - excessive sweating
  - diabetes insipidus (ADH) = loss of hypotonic urine
- increased intake of salt
- coma, no responce to thirst

Therapy: Glc 5% i.v.

Potassium K+

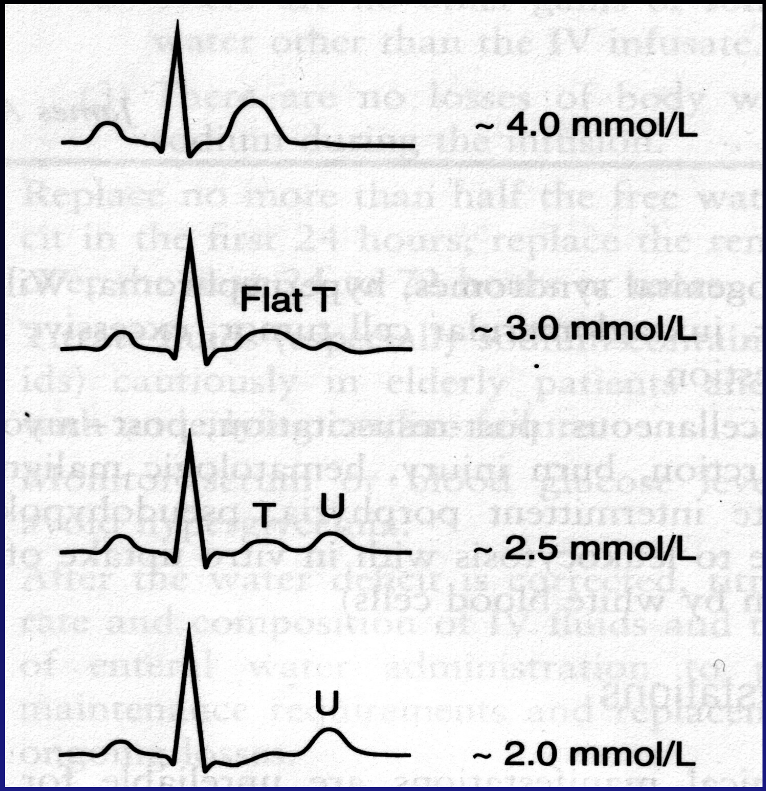
- Major intracellular cation
- serum (2% of total) 3.8 .. 5.6 mmol/l
- electric potential on membrane (Na+/K+ ATPasa)
- arytmias

- extremly responsive to changes of pH!!

Acidosis in cell (H+) banish K+ out of cell.

delta pH 0,1 ..... 0,5..0,6 mmol/l (i.v.)

Hypokalemia K < 4 mmol/l

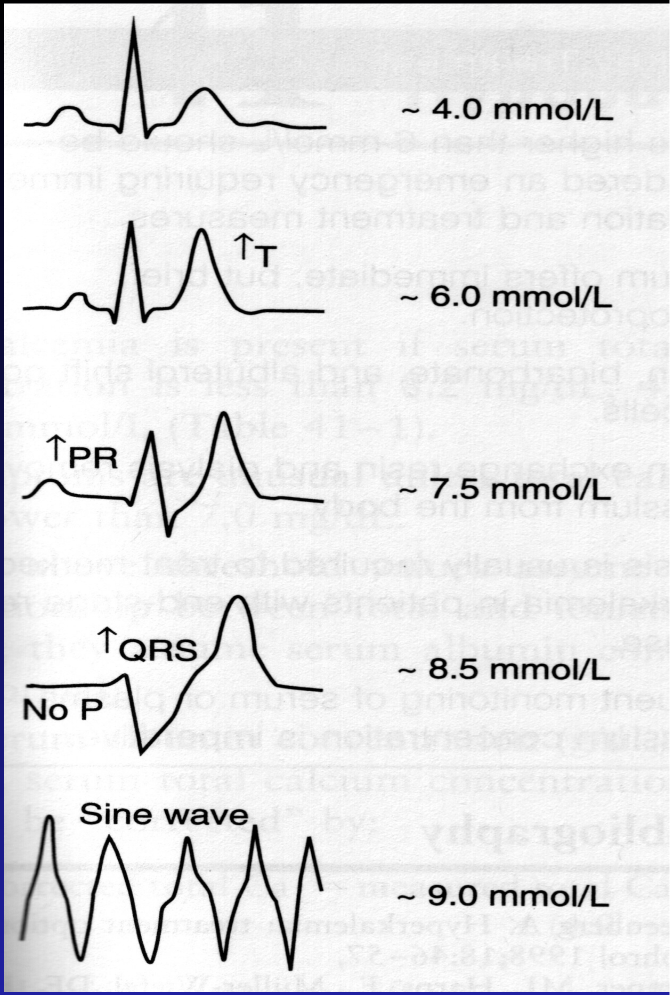


- losses in urine
- diurettics, diarrhea, vomiting
- reduced intake
- Alcalosis
- CAVE severe muscle weakness, asystolia

Treatment:

- KCl p.os; max KCl 40 mmol/h i.v.
- ECG monitoring !!!!

Hyperkalemia



- hemolysis
- muscle damage
- anuria, renal failure
- Acidosis

- CAVE intracardiac block (diastolic arest) or fibrilation
  - muscle weakness – ventilatory failure

therapy:

- stop intake
- Glc + HMR i.v., loop diuretic (furosemide)
- Calcium i.v., bicarbonate i.v
- resonium p.os
- dialysis

Calcium Ca++

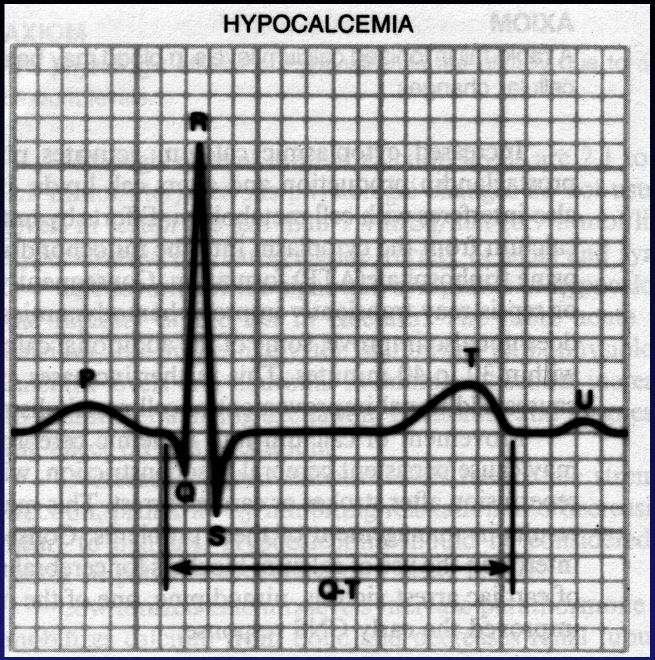
- most abundant mineral in the body 2kg
- Parathormone PTH
  - stimulate osteoklast
  - stimulate intestine
  - resorption in kidney
- Calcitonin
  - inhibites osteoklast
- Vitamine D
  - potens saving Ca++

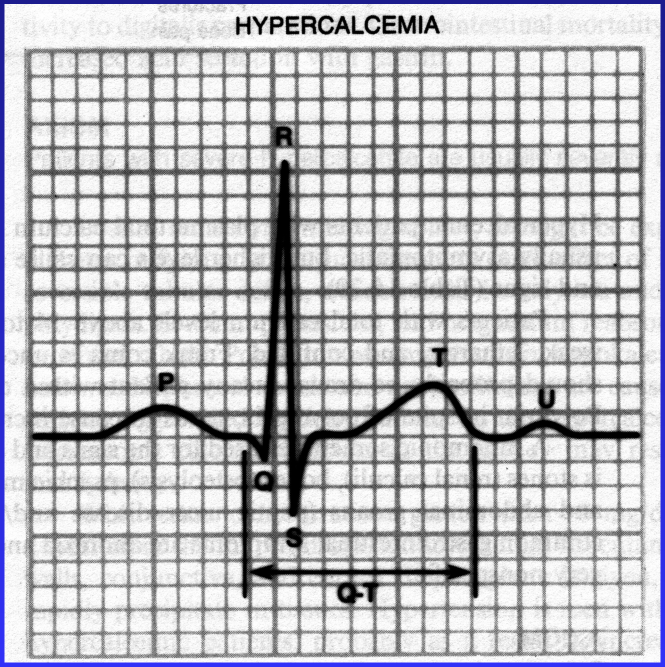
Ionised Ca = 1.1 mmol/l // efect of all Calcium

bound by proteins =ineffective to receptors

Calcium Ca++

- Hypocalcemia
  - Respiratory Alcalosis, hypoPTH,
  - shock, sepsis, pancreatitis
  - together hypomagnesemia
- Hypercalcemia
  - muscle damage
  - malignancy





Chloride Cl-

- Major anion in Extracellular fluid
- see ABR

Glucose

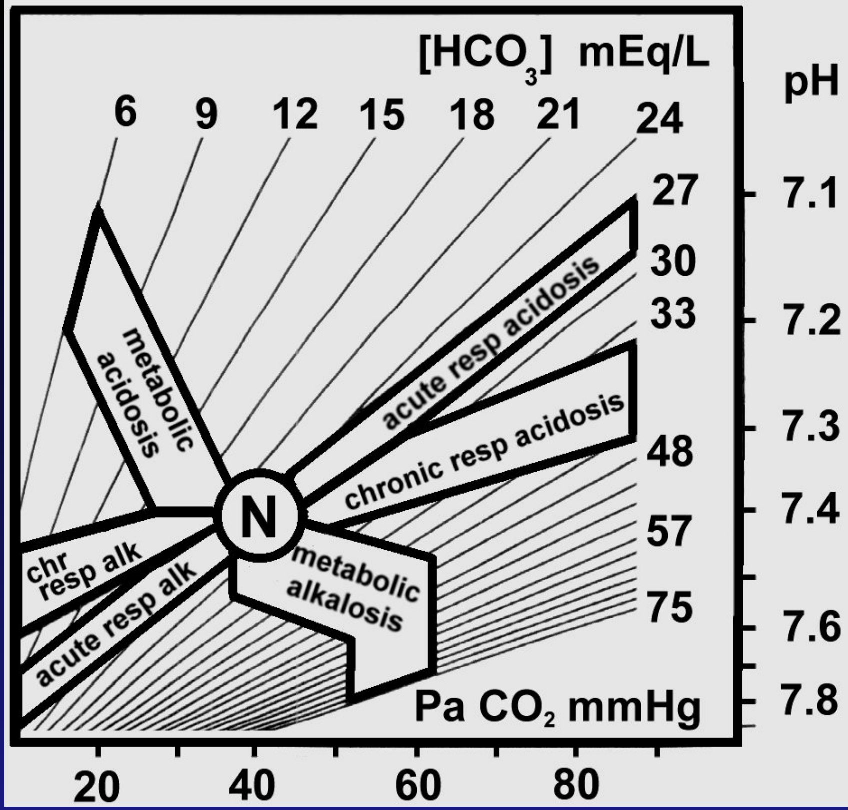
- hyperglycemia
- hypoglycemia / insulin overdose/

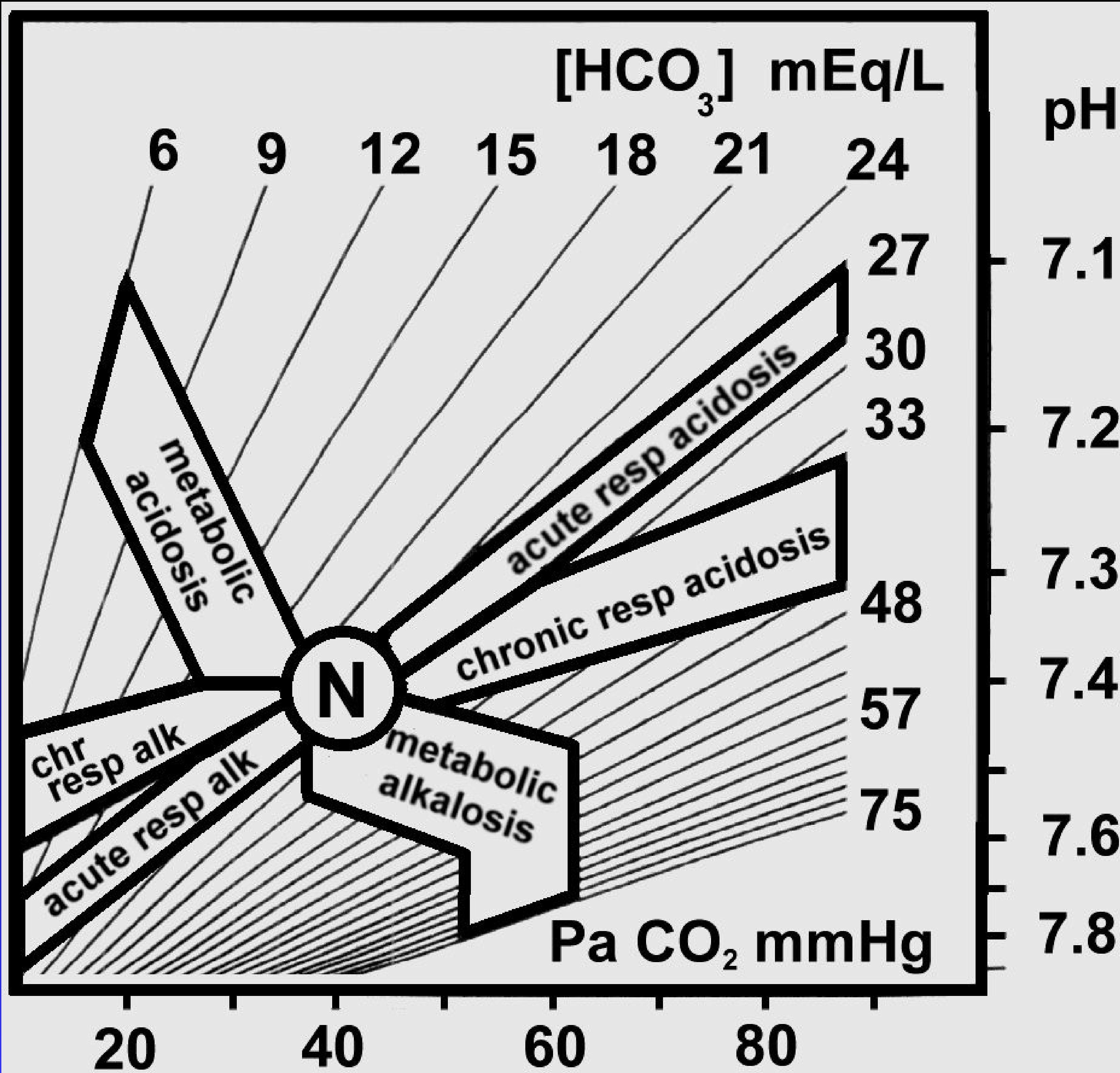
- next week

Acide-base

arterial blood:

pH	7,35-7,45
pCO_2	4,6-6 kPa
pO_2	10-13 kPa
HCO_3^-	22-26mmol/L
BE	-2 .. +2 mmol/L
SpO2	95-98%





[HCO3] mEq/L
pH
6
9
12
15
18
21
24
27
30
33
48
57
75
7.1
7.2
7.3
7.4
7.6
7.8
metabolic acidosis
acute resp acidosis
chronic resp acidosis
N
chr resp alk
acute resp alk
metabolic alkalosis
Pa CO2 mmHg
20
40
60
80

Arterial Blood Gas Analysis

ABG Parameter			ABG result
pH	>7.45	Alkalaemia	
	7.36-44	Normal	
	<7.35	Acidaemia	
pCO2	>45	High	
	35-45	Normal	
	<35	Low	
HCO3	>26	High	
	24+/- 2	Normal	
	<22	Low	
AG	> 16	High	
	12+/-4	Normal	
	< 8	Low	
Glucose	>10	High	
	< 2	Low	
Gap: Gap	$\frac{\Delta AG}{\Delta HCO_3} = \frac{AG - 12}{24 - HCO_3}$		
Lactate	**<1.9**	Normal	
	>2.0	High	
pO2	80-100	Normal	
	< 80	Hypoxia	

Calculation and interpretation

pH	pCO2	Interpretation
↓	↓	Metabolic acidosis
↑	↑	Metabolic alkalosis
↑	↓	Respiratory alkalosis
↓	↑	Respiratory acidosis

Corrected standard AG for albumin

$$\frac{\text{Albumin}}{4} + 1.5 \times \text{Phosphate}$$

Anion Gap calculation

$$\{[Na+] - [Cl^- + HCO_3]\} = 12+/-4$$

Corrected Na+ for AG in hyperglycemia

$$\text{Corrected Na+} = \text{Na} + \frac{\text{Glucose} - 5}{3}$$

Gap: Gap calculation for metabolic acidosis

<0.4	Low or Normal AG metabolic acidosis
0.4-0.8	Normal + high AG metabolic acidosis
0.8-2.0	Pure high metabolic acidosis
>2.0	Metabolic acidosis with metabolic alkalosis/respiratory acidosis

$$\text{PAO2} = [713 \times \text{FiO2}] - [\text{pCO2} \times 1.25]$$

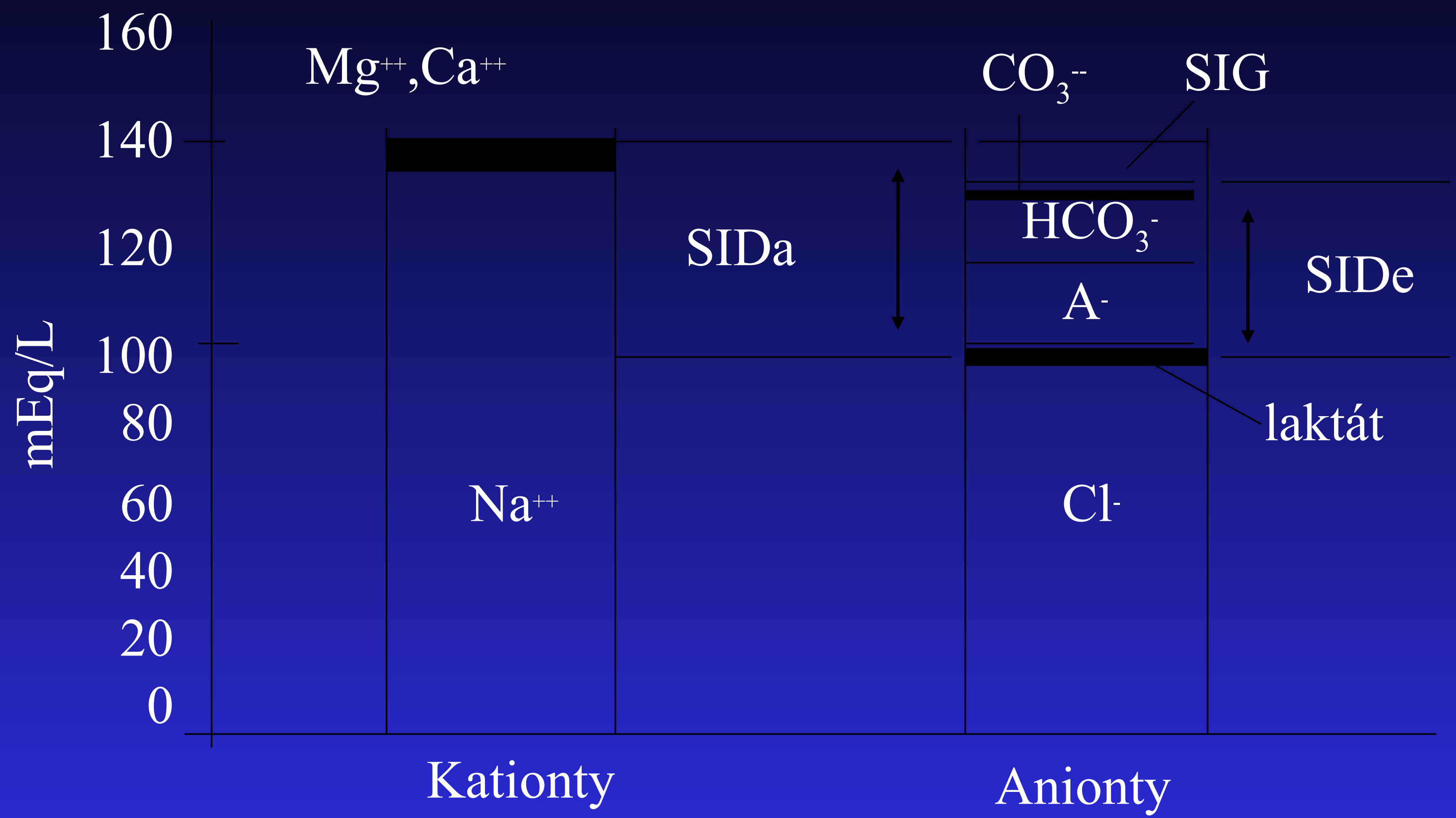
$$\text{A-a gradient} = \text{PAO2} - \text{PaO2} = \frac{\text{Age}}{4} + 4$$

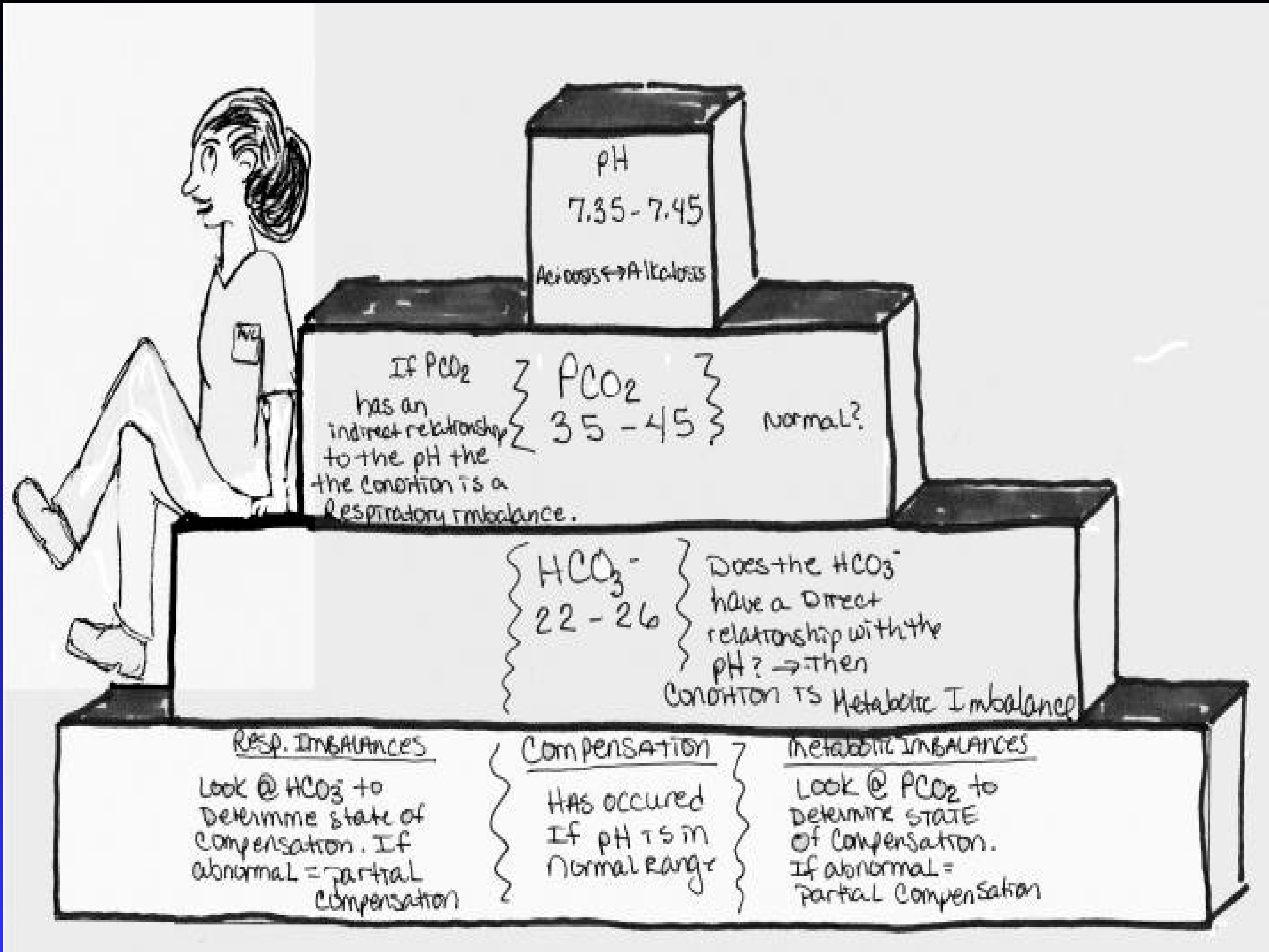
Compensation rules for

	Metabolic acidosis	Metabolic alkalosis
Expected PCO2	1.5 X [HCO3] + 8 (+/- 2)	0.7 X [HCO3] + 20 (+/- 5)

	Respiratory acidosis		Respiratory alkalosis	
	Acute	Chronic	Acute	Chronic
Expected HCO3	$24 + \frac{pCO2 - 40}{10} \times 1$	$24 + \frac{pCO2 - 40}{10} \times 4$	$24 - \frac{40 - pCO2}{10} \times 2$	$24 - \frac{40 - pCO2}{10} \times 5$

Steward's principle




pH
7.35 - 7.45
Acidosis ↔ Alkalosis
If PCO2 has an indirect relationship to the pH the the condition is a Respiratory imbalance.
PCO2
35 - 45
normal?
HCO3-
22 - 26
Does the HCO3- have a Direct relationship with the pH? → then condition is Metabolic Imbalance
Resp. Imbalances
Look @ HCO3 to Determine state of Compensation. If abnormal = partial compensation
Compensation
Has occured If pH is in normal range
Metabolic Imbalances
Look @ PCO2 to Determine state of Compensation. If abnormal = partial compensation

My 4 Steps to figure out the Patients ABGs

If I were to start on the top step going down, I would decide if my patient has acidosis or alkalosis by looking at his pH level. If it is normal but the PCO2 or HCO3- is off, I would keep looking knowing that compensation may have happened.

- If the PCO2 has an indirect relationship to the pH (if pH is high, but PCO2 is low or if pH is low and PCO2 is high) then I will know the patients condition is Respiratory. (involving the lungs) Either Respiratory Alkalosis or Respiratory Acidosis depending on the pH.
- If the HCO3- has a direct relationship or is normal (if pH is high, and HCO3- is high, or if pH is low and HCO3- is low), then I know the problem is Metabolic (involving the kidneys). Either Metabolic Acidosis or Alkalosis – dependent upon the abnormal value of the pH.
- Lastly I would use my bottom step to decide the compensation. Has there been compensation? If the pH is normal, then the body has been working to get it's pH values back to normal. If it isn't normal, I would look at the HCO3- for Respiratory (we didn't look at this one early on for Respiratory), or I would look at PCO2 for Metabolic (we didn't look at this one for Metabolic). – Generally, if all values are off: you have partial compensation (the body is still trying to compensate).

CO2

$$Glc + O_2 \rightarrow CO_2 + H_2O$$

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

ΔpH	Δ p CO2
0.1	1,6 kPa = 12 mmHg

Respiratory Acidosis (↓ pH_a & ↑ P_{aCO2})

Hypoventilation

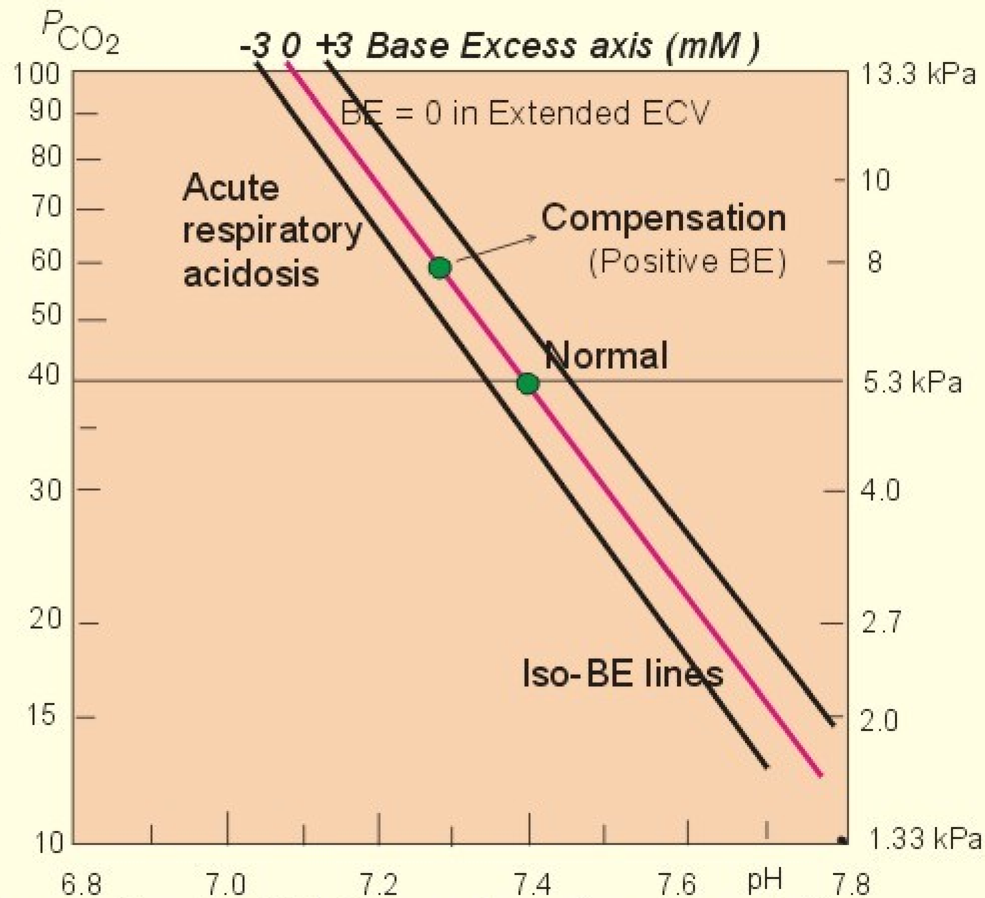
Increase ↓

$$CO_2 + H_2O \xrightarrow{*} H_2CO_3 \rightarrow H^+ + HCO_3^-$$

$$HB \longrightarrow H^+ + B^-$$

Rise in HCO_3^- = fall in B^-

BE = 0



Causes: Anoxia, COLD, near drowning, strangulation

Fig. 17-9

KMc

Genesis of Acid = donor of H^+

- lactate - shock
- strong acids intake (HCl, H_2SO_4)
- acetylsalicilic acid (drug overdose)
- ...

ΔpH	Δ BE
0.1	6mmol/l

Basic laws

$pH = -\log [H^+]$ $[H^+]$ ... mol/l

$pH = pK + \log (H^+ \text{ acceptor} / H^+ \text{ donor})$

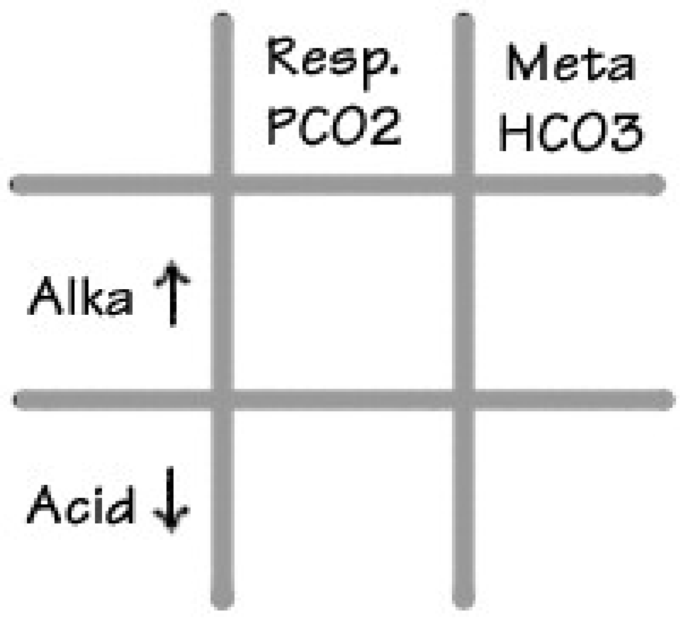
$[H^+] = 24 \times paCO_2 / [HCO_3^-]$ Henderson equation

- acidosis $pH < 7.36$
- alcalosis $pH > 7.44$

Place of error:

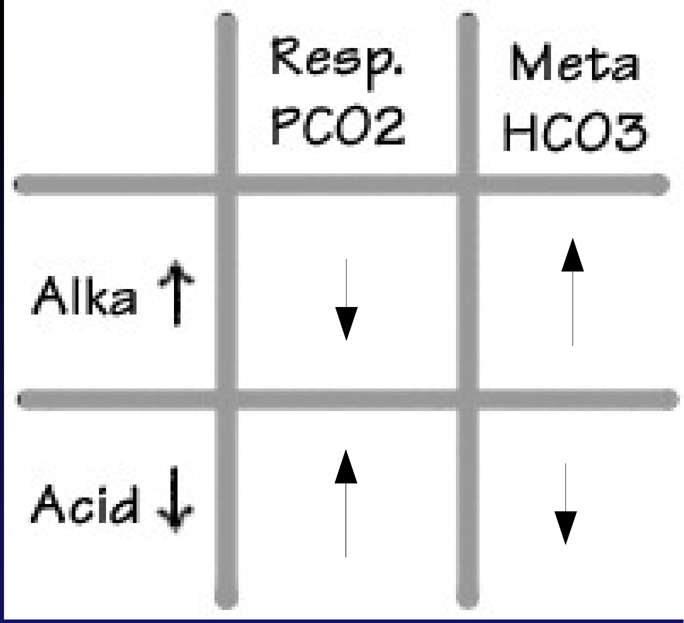
- Respiratory (lung) ... pCO_2
- Metabolic (kidney,...) ... BE

BE = number of acid needed to correct sample to pH 7.4



Easy equation

ΔpH	BE	Δ p CO2
0.1	6mmol/l	1,6 kPa = 12 mmHg



Easy equation

↓ ΔpH	↓ BE	↑ $\Delta\ p\ CO_2$
0.1	6mmol/l	1,6 kPa = 12 mmHg

Kilopascals for PCO_2.

- Many texts and papers express the PCO_2 in kilopascals (kPa). It is useful to remember that this value is almost the same as the percentage of atmospheric pressure. For example, the normal arterial PCO_2 of 40 mmHg is 5.33 kPa or 5.61 %.

- To convert pressure in mmHg to kPa, it is necessary to divide the value in mmHg by 7.5
- [40mmHg /7,5 = 5,33kPa]

Respiratory Acidosis (RAc)

- The **decision to ventilate** a patient to reduce the PCO_2 is a clinical decision and is based on exhaustion, prognosis, prospect of improvement from concurrent therapy, and in part on the PCO_2 level. Once the decision is made, the PCO_2 helps to calculate the appropriate correction.
- The PCO_2 reflects a **balance** between the carbon dioxide production and its elimination. Unless the metabolic rate changes, the amount of carbon dioxide to be eliminated remains constant. It directly determines the amount of ventilation required and the level of PCO_2. Where V_T equals tidal volume and f equals respiratory rate:
- PCO_2 x Ventilation = Constant, i.e.,
  $PCO_2 \times V_T \times f = k$

MAc

- **kidney unable to eliminate H^+ = anuria**
- **big production of acides.**

- The treatment for a metabolic acidosis is, again, judged largely on clinical grounds. Bicarbonate therapy is justified when metabolic acidosis accompanies difficulty in resuscitating an individual or in maintaining cardiovascular stability.
- A typical dose of bicarbonate might be 1 mEq per kilogram of body weight followed by repeat blood gas analysis.
- Calculation is based on BE and the size of the treatable space (0.3 x weight, e.g., 21 liters):

Dose (mEq) = 0.3 x Wt (kg) x BE (mEq/L).

Serum Anion Gap

Cations	**Anions**
Na^+, K^+, Ca^+, Mg^+	Cl^-, HCO_3^-, PO_4^-, SO_4^-, Albumin, organic acids (OA)

$$[Na^+] + UC = [Cl^-] + [HCO_3^-] + UA$$

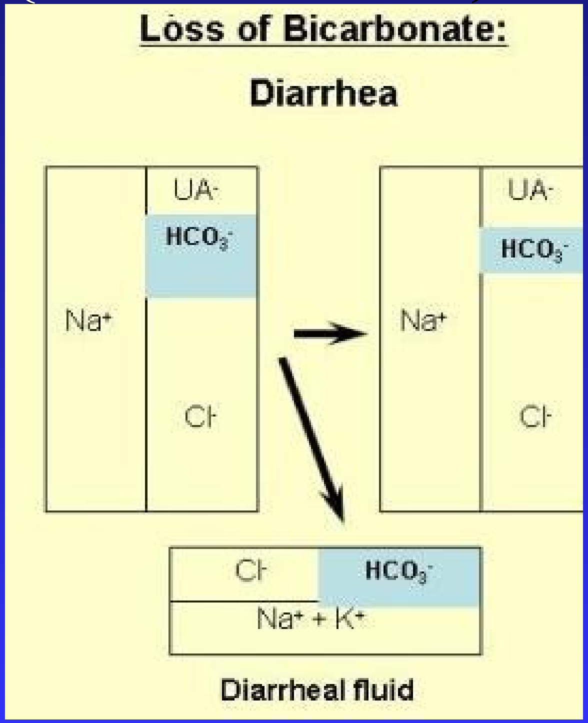
$$UA - UC = [Na^+] - ([Cl^-] + [HCO_3^-])$$

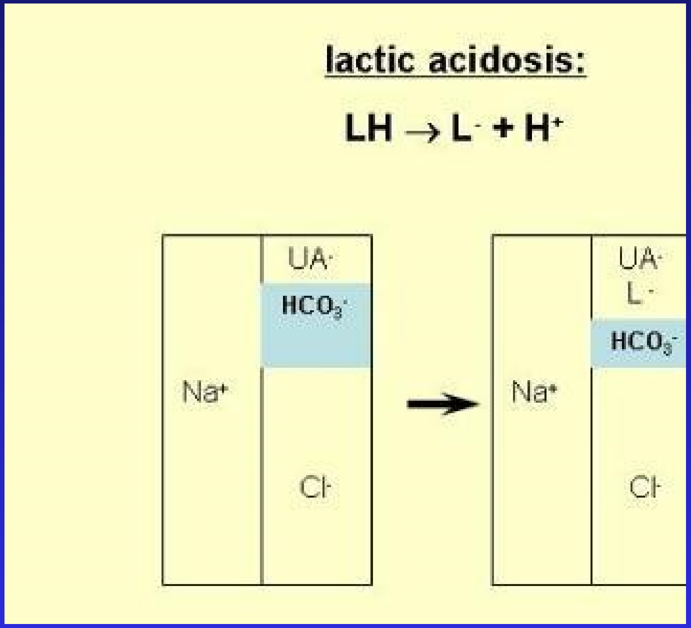
$$\text{Anion gap} = [UA] - [UC] = [Na^+] - ([Cl^-] + [HCO_3^-])$$

UC, unmeasured cations; UA, unmeasured anions

Metabolic Acidosis

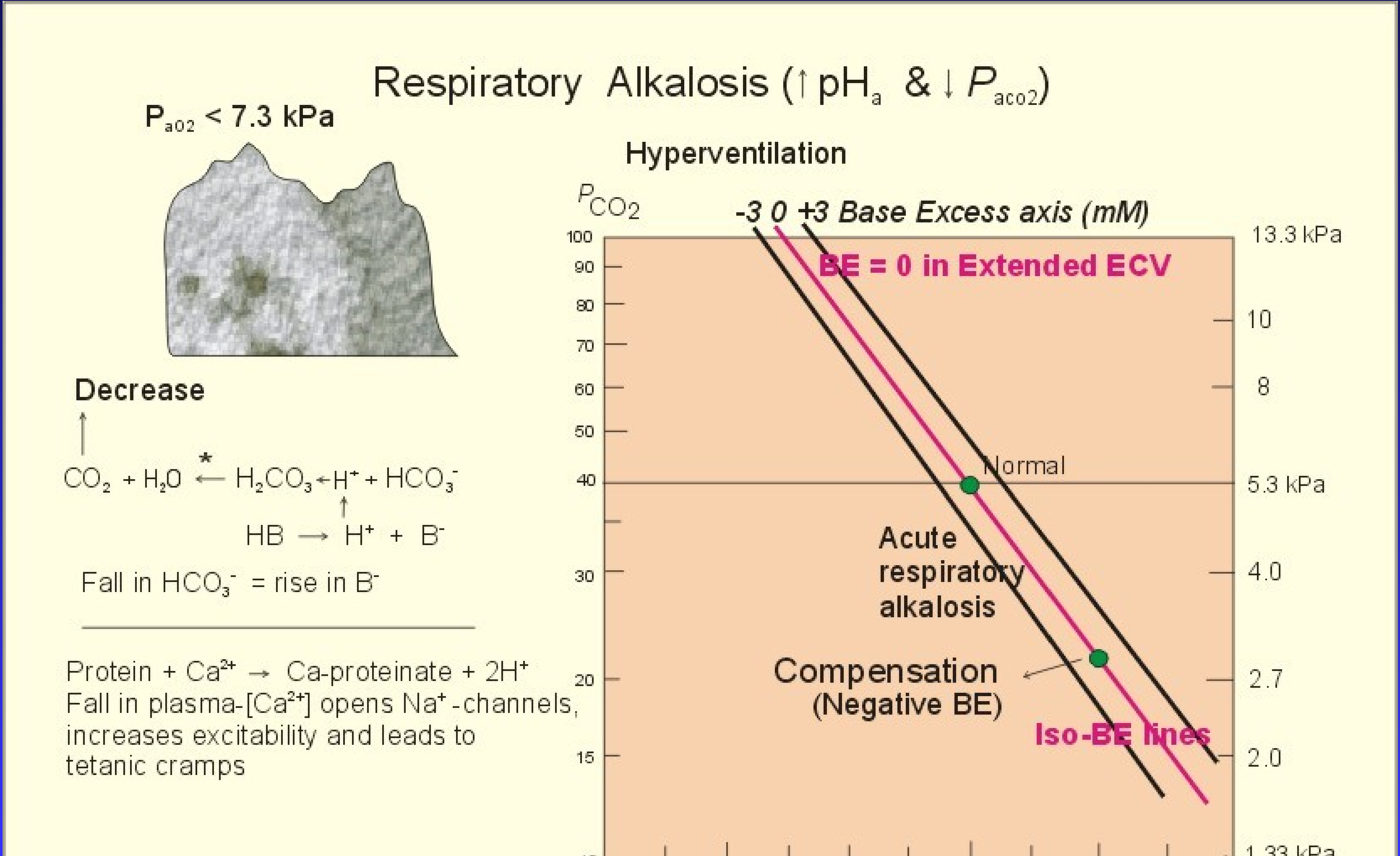
- Unmeasured Anions {organic acids - lactate, …}
- Cl-
- loss of HCO3, Na,K,Cl
  {diarrheal fluid, wrong ratio}





RAl

- hyperventilation
- lost of ionized Calcium / hypocalcemia / tetania



MAl

- increased loss of NH4 to urine
- saving HCO3- by kidney
- loss of Cl- (vomiting)
-
- BE > O
- pH > 7.44
- Th: i.v. FR (NaCl)
-

How to

1. what is wrong
2. what the body do
3. what to do

OR / AAA, 5 000ml lost, haemorh. shock, NA i.v., general anesthesia, VCV

pH akt.	7.083	(7.350 - 7.450)	<-( )
pCO_2	6.36 kPa	(4.80 - 5.90)	( )->
pO_2	30.78 kPa	(10.66 - 13.30)	( )=>
BE	-15.8 mmol/l	(-2.6 - 2.6)	<=( )
BB	32.1 mmol/l	(40.0 - 44.0)	<=( )
HCO_3 akt.	13.9 mmol/l	(22.0 - 26.0)	<=( )

OR / AAA, 6 500ml loost, haemorh. shock, NA i.v.

pH akt. 7.1 (7.350 - 7.450) <=( )

pCO2 5.0 kPa (4.80 - 5.90) (*)

BE -18 mmol/l (-2.6 - 2.6) <=( )

lactate 13 mmol/l (1 – 2.5) ( )= =>

Try it yourself

pH = 7,2

pCO2 = 14 kPa

BE = 20 mmol/l

pH 7,35-7,45

pCO_2 4,6-6 kPa

pO_2 10-13 kPa

HCO_3^- 22-26mmol/L

BE -2 .. +2 mmol/L

SpO2 95-98%

- polytrauma + sepsis + ARDS

Measured		Calculated	
Na	131 ↓	HCO_3^-	21 ↓
K	4,2 =	BE	-4 ↓
Mg	3,6 ↑		
Ca	2,2 =		
Cl	86 ↓		
Pi	2,3 ↑		
Alb	8 ⇊		
pH	7,31 ↓		
$PaCO_2$	5,4 =		

- polytrauma + sepsis + ARDS

Henderson-Hasselbach:

- metabolic acidosis

Measured		Calculated	
Na	131 ↓	HCO_3^-	21 ↓
K	4,2 =	BE	-4 ↓
Mg	3,6 ↑		
Ca	2,2 =		
Cl	86 ↓		
Pi	2,3 ↑		
Alb	8 ⇊		
pH	7,31 ↓		
$PaCO_2$	5,4 =		

- polytrauma, sepse s ARDS

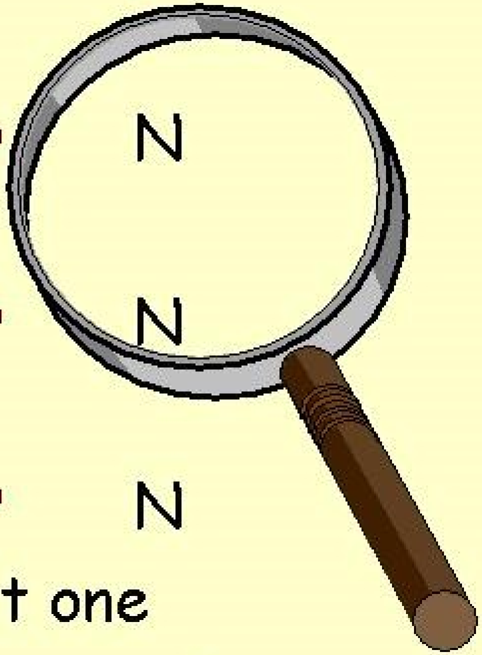
Measured		Calculated	
Na	131 ↓	HCO_3^-	21 ↓
K	4,2 =	BE	-4 ↓
Mg	3,6 ↑		
Ca	2,2 =		
Cl	86 ↓		
Pi	2,3 ↑		
Alb	8 ⇊		
pH	7,31 ↓		
$PaCO_2$	5,4 =		

Stewart-Fencl:

- lactic acidosis
- dilution acidosis
- hypochloremic alkalosis
- hypoalbuminemic alkalisis

#3 example

- pH 7.45 — N
- PCO2 43 — N
- HCO3- 25 — N
- this is the hardest one for beginners... **it's normal**



SUMARY

- Biologic system react primary to rate of change and not to absolute concentrations.
- Abnormalities should be treated at proximately the rate at which they developed.
- DO NOT rapid correction of a chronic asymptomatic abnormality.

When order electrolytes exam:

- poor oral intake
- vomiting
- chronic hypertension
- diuretic use
- recent seizure
- muscle weakness
- age over 65
- alcoholism
- history of electrolyte abnormality

When order blood gasses:

- acid-base problems
- artificial ventilation
-

acute CNS change

immediately look for

- hypoxemia
- hypoglycemia
- hyponatremia
- sepsis

Priorities

1. fluid volume and perfusion deficits
2. correction of pH
3. K, Ca, Mg
4. Na, Cl

Bleeding – transfusion strategy

Indication:	Transfuse to Maintain:
• Transfuse any symptomatic patient (e.g., tachycardia, hypotension, CHF, angina)	• Until no longer symptomatic
• Asymptomatic, presurgical, stable patient	• Hb 7-8 g/dl
• Hemodynamically stable postsurgical stable patient	• Hb 8 g/dl
• Postsurgical patient at risk for ischemic disease (e.g., cardiac, bowel)	• Hb 10 g/dl
• Hemodynamically stable, nonpregnant, ICU patients >age 16 without ongoing blood loss	• Transfuse at 7 g/dl to maintain Hb at 7-9 g/dl