Violations of acid-base balance in the clinic of emergency conditions.

Ershov V.I.

Doctor of Medical Sciences, Professor of the Department of Anesthesiology and Reanimatology OrGMA

What is an acid?
The "traditional definition"

- Substance with certain properties (acid taste, changes the color of the indicator - litmus, etc.)

The Arrhenius theory (1887)

- Acid is a substance that dissociates in the aqueous solution to H^+
- Foundation - to OH^-
- Neutrality - $[H^+] = [OH^-]$
- Limitations: - some substances with acids, do not contain H^+, and bases - OH
- - considers only aqueous solutions

The Bronsted-Lowry theory (1923)

- The most common in modern medicine
- Acid - donor [H+]
- The base is an acceptor of [H+]
- Each donor [H+] has its corresponding acceptor-conjugated pair
- A strong acid easily gives [H+] a water molecule → ↑ [H3O+]
- There is no concept of "electroneutrality"

The Lewis theory (1923)

- The stimulus was the presence of substances (e.g., CO_2) exhibiting properties acids in solution, but do not have a composition of $[H^+]$
- Acid is a potential acceptor of an electron pair
- The base is a potential donor of the electron pair
- According to Lewis, $[H^+]$ is itself an acid

The Usanovich theory(1939)

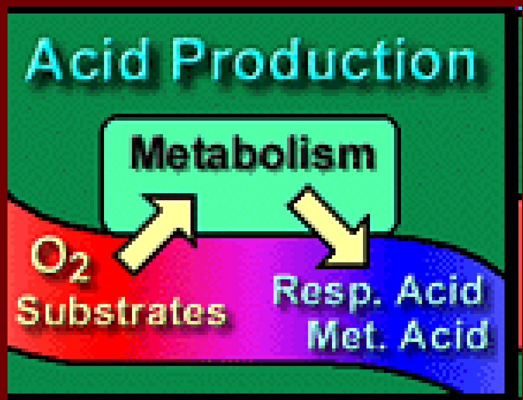
- An acid is a substance that is a cation donor or an acceptor of an anion or an electron
- A base is a substance that is an anion donor, or a cation acceptor

What theory is used in practice?

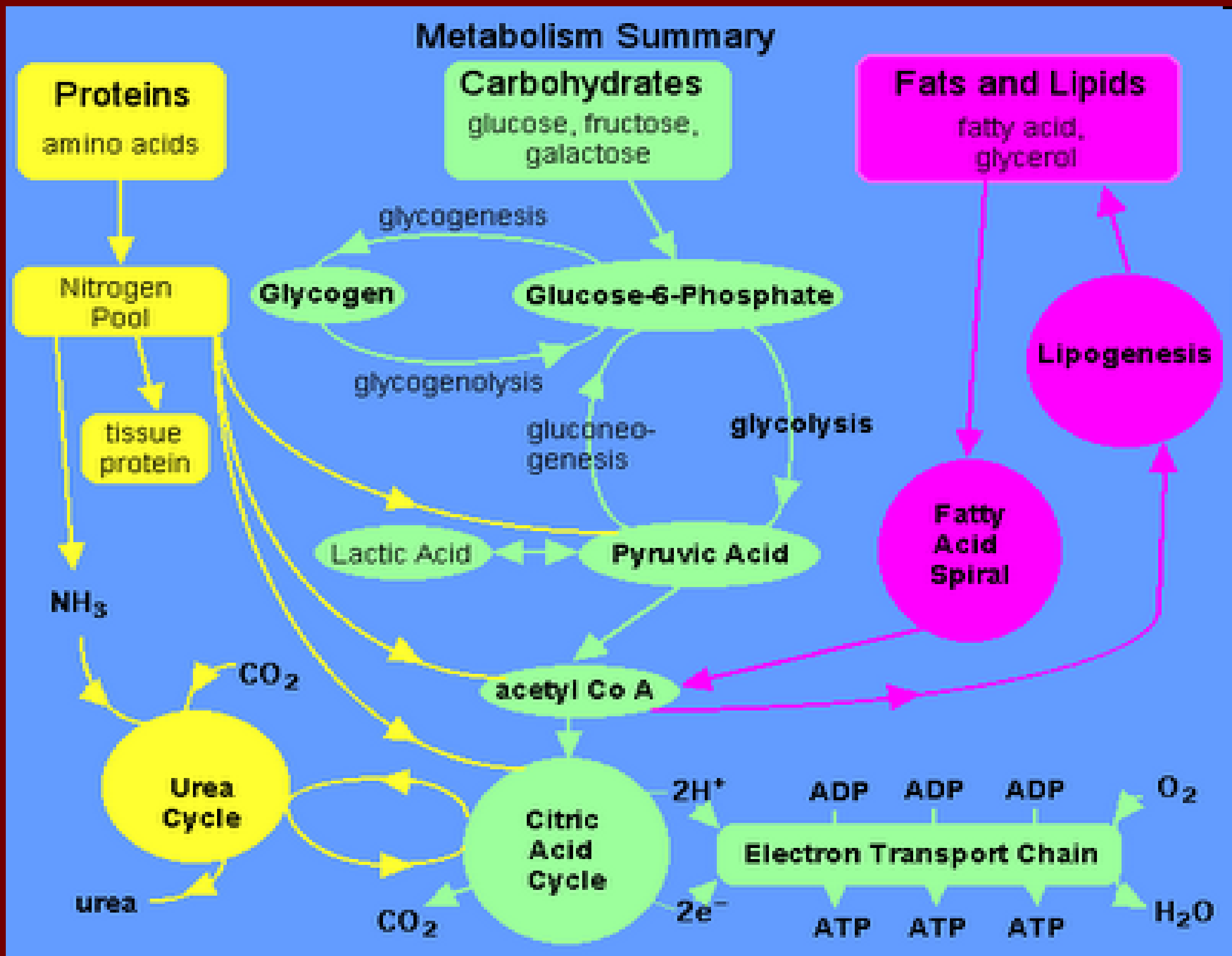
- Easier than others - Bronsted-Lowry. Use H_2CO_3 instead of CO_2
- In practice, most of us understand acid as:
- - $[H^+]$ in solution (Arrhenius)
- - donor $[H^+]$ (Bronsted-Lowry)
- - and even CO_2, as an "acid" (Lewis)

Where does "acid" come from in the body?

- Respiratory (volatile) acid
- Metabolic (fixed) acids



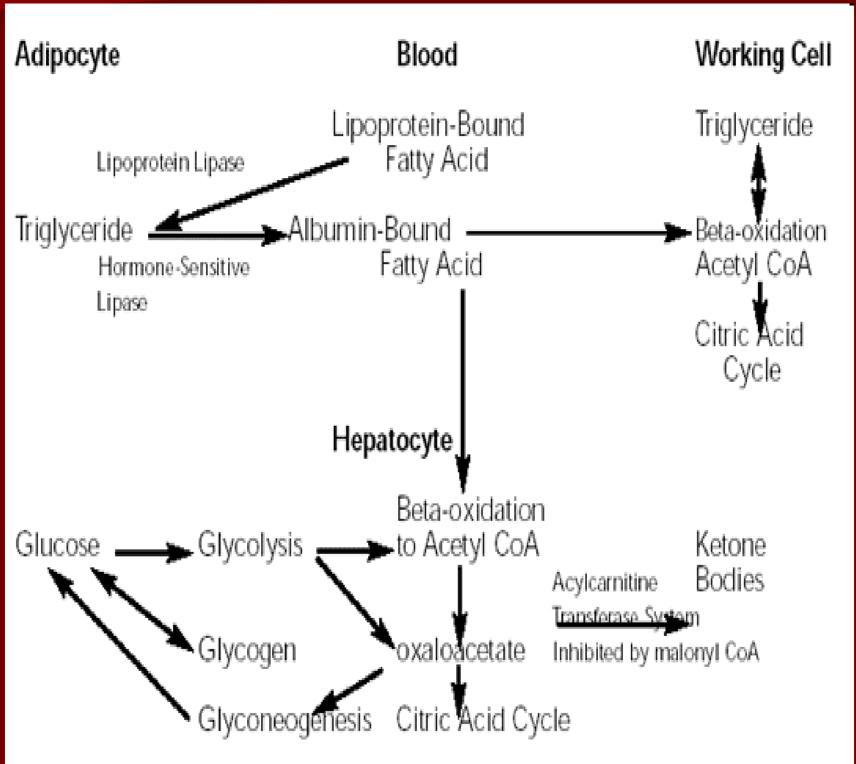
The only source of CO_2 - the metabolism of carbohydrates and fats

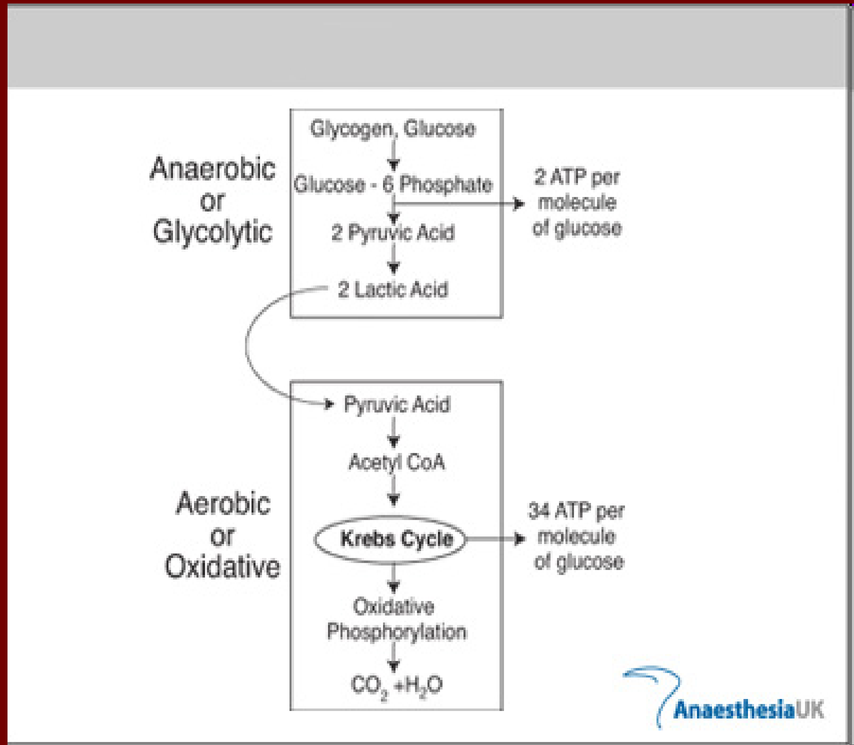


Metabolic (non-volatile) acids

- All acids except H2CO3!
- As a rule, they are called by their anion - for example, lactate, phosphate, sulfate, acetoacetate, β-hydroxybutyrate)
- In adults, 70-100 mmol H + / day is produced as a result of incomplete metabolism of carbohydrates (lactate), proteins (sulfate, phosphate), fats (ketones).
- Excreted by the kidneys

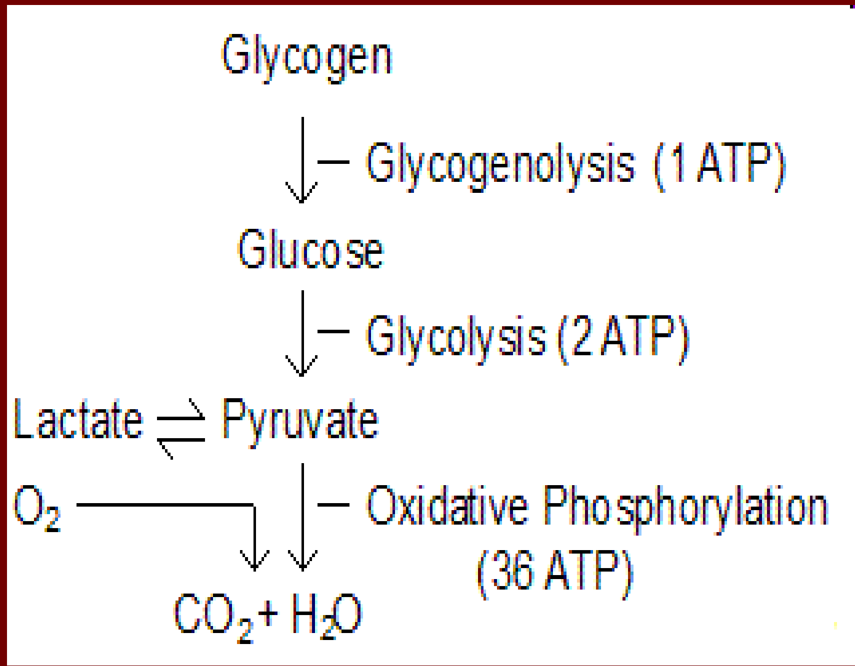
Ketones are a product of uncompleted fat metabolism; lactate - carbohydrates





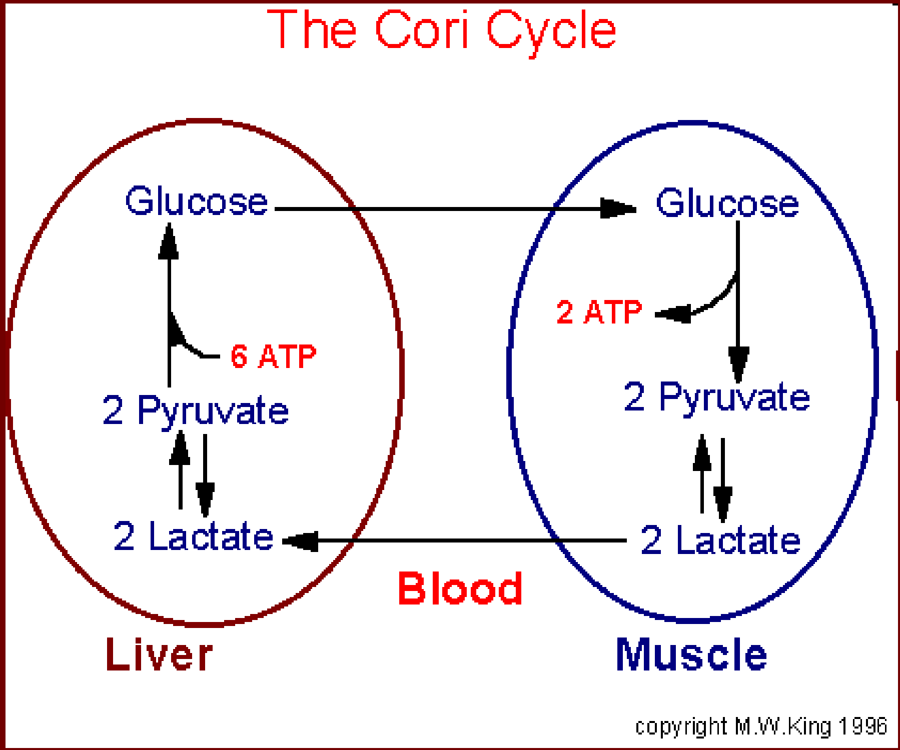
Lactate - note 1

- Normally, most of the lactate is metabolized (lactate-pyruvate) - the problem of excretion is not worth it



Lactate - note 2

- But only in the liver and kidney lactate can be converted back to glucose (gluconeogenesis), and not to CO2 - the Corey cycle

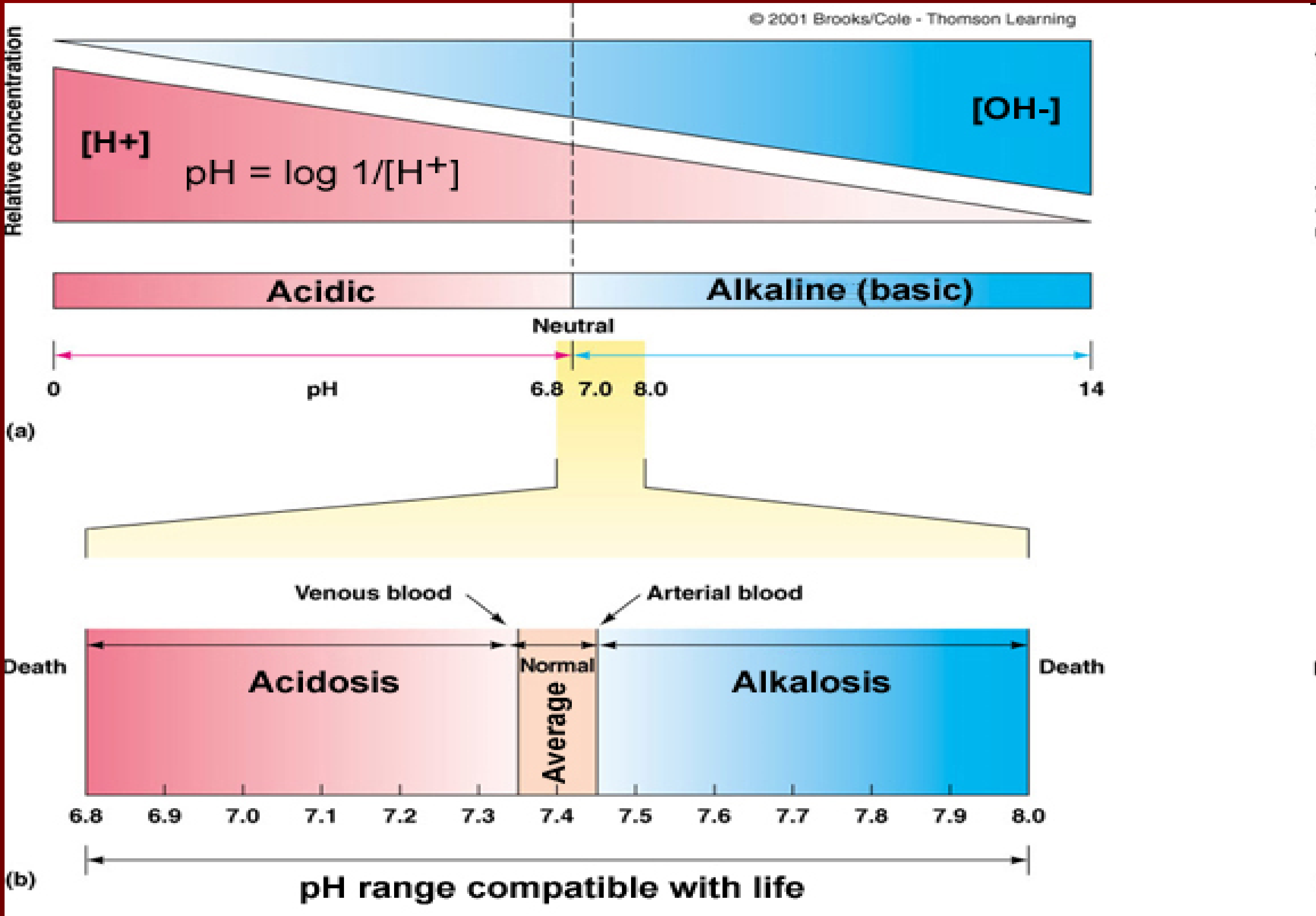


The content of [H +] in plasma is mainly determined by the relation between the partial pressure of carbon dioxide (PaCO2) and bicarbonate anions (HCO3-)

$$H^+ \text{ (нмоль/л)} = 24 \frac{PaCO_2}{HCO_3}$$

The pH of the blood - *the negative decimal logarithm of the concentration of hydrogen ions, is determined by the Henderson-Hasselbalch equation*

$$pH = pK_A + \log \frac{[HCO_3^-]}{(PaCO_2 \ x \ 0,0308)}$$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Relative concentration
[H+]
[OH-]
pH = log 1/[H+]
Acidic
Alkaline (basic)
Neutral
0
pH
6.8
7.0
8.0
14
(a)
Venous blood
Arterial blood
Death
Acidosis
Normal
Average
Alkalosis
Death
6.8
6.9
7.0
7.1
7.2
7.3
7.4
7.5
7.6
7.7
7.8
7.9
8.0
(b)
pH range compatible with life

Advantages of using pH

- Traditional, widely used designation
- Reflects the activity of H + but not concentration (see the pH-electrode device is further) - real feature physiological systems
- H + is not present in solutions in pure form

disadvantages pH

- Derivative, reflecting double nonlinear transformation [H +] (i.e. 1. negative 2. logarithm)
- It is difficult to understand and remember
- Underestimates the degree of change in concentration [H +]

Easy way to convert pH and $[H^+]$

- pH - 7.4 = [H +] - 40 nmol / l
- An increase / decrease of [H +] by 2 times leads to a change in pH by 0.3 in the other direction. (log 2 = 0.3)
- For example, if [H +] is 80 nmol / l → pH = 7.1

Buffer systems

- **THE ORGANISM POSSESSES HUGE BUFFER OPPORTUNITIES!**
- **BUFFERS - INSTANT RESPONSE SYSTEMS!**
- **Buffering masks the real changes [H +] - we estimate the degree of violation of KOS by reducing the buffer anions A-, which are associated with H +, forming HA**

Buffer systems

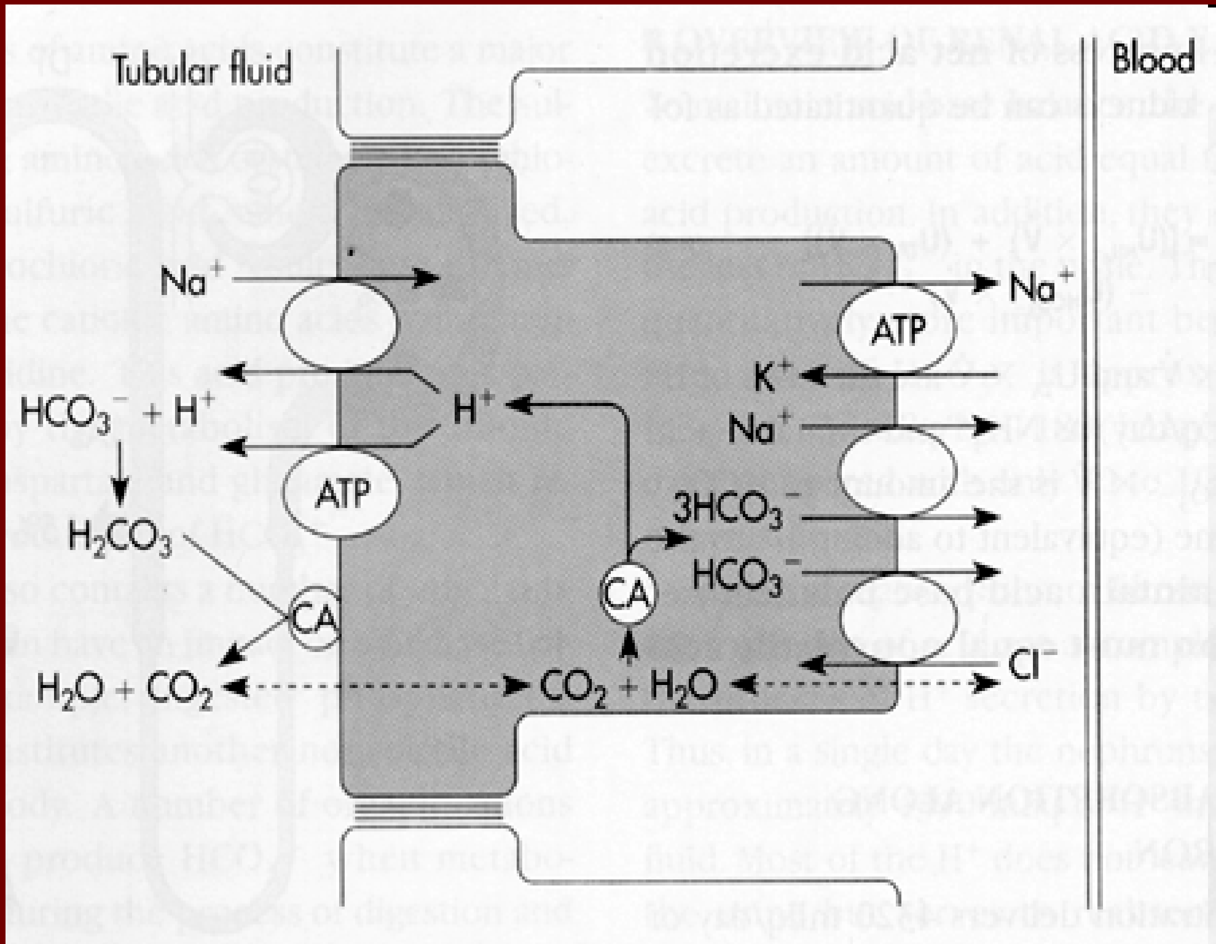
Blood	Bicarbonate	Important for binding the "metabolic" acid
	Hemoglobin	Important for CO2 neutralization
	Plasma proteins	Minor buffer
	Phosphate	Concentration too low
Intracellular fluid	Proteins	Important buffer
	Phosphate	Important buffer
Urine	Phosphate	Responsible for neutralizing most of the “titrated acid”
	Ammonium	Important - the formation of NH4 +

CO2-bicarbonate buffer system

- The most important buffer in the extracellular fluid is 80% buffering.
- $CO_2 + H_2O \Leftrightarrow H^+ + HCO_3^-$
- pH = 6.1 + log ([HCO3] / 0.03 pCO2)? The system is open “at both ends” - CO2 is rapidly removed from the body - maintaining a normal pH, despite the low pKa (6.1) of the buffer.
- Control only metabolic, but not respiratory acid !!!

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

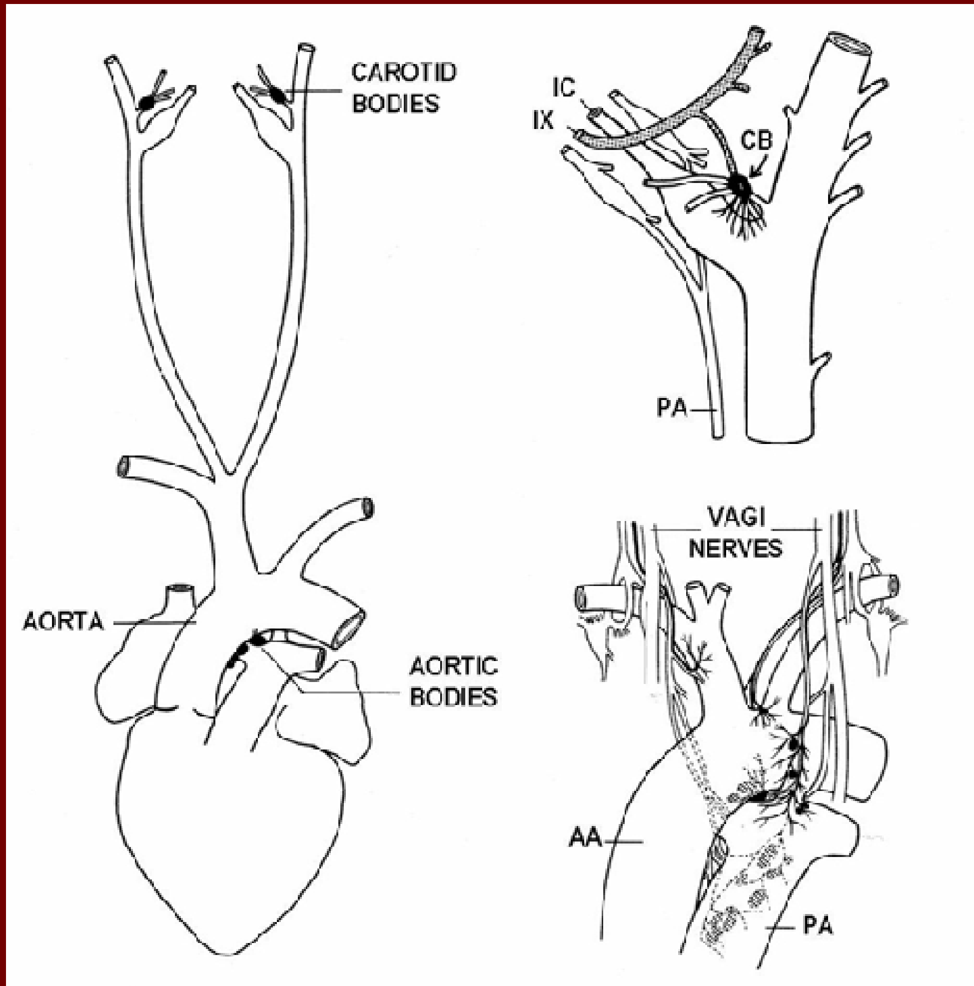
Bicarbonate reabsorption in proximal tubules.



Hemoglobin and blood proteins

- Blood proteins (70 g / l) and hemoglobin (150 g / l)
- Buffering the imidazole ring of histidine (see above). pKa - 6.8
- Hemoglobin is important not only because of the higher concentration, but also due to the fact that it contains 3 times more histidine groups than proteins.
- Deoxyhemoglobin binds H + (more efficient buffer) better than oxyhemoglobin - Haldane effect - 30% due to changes in the buffer capacity (see below)

Peripheral chemoreceptors are sensitive to CO_2, O_2 и pH.



$PaCO_2$

35 – 45 mm Hg

PaO_2

50 – 80 mm Hg

Standart bicarbonate (SBC) – the concentration of all forms of bicarbonate in the blood plasma at PaCO2 = 40 mm Hg, body temperature 38 ° C and 100% blood oxygenation.

Normally equal to 24 mmol / l. It characterizes the degree of influence of metabolic processes on blood COS, completely excluding the effect of respiration on this indicator

Actual bicarbonate (ABC)

the content of HCO_3^- in the blood of the patient under given specific conditions, the calculated figure

BD/BE (Base deficit/base excess) – show how many millimoles of acid or base should be added to 1 liter of blood to bring the pH to 7.4 with PaCO2 = 40 mm Hg, body temperature 38 ° C, protein content 70 g / l, hemoglobin 150 g / l and 100% oxygen saturation .

The parameter allows to assess the degree of metabolic disorders of metabolic disorders and metabolic compensation of respiratory disorders. The norm is the deviation of the parameter within ± 2.

The higher the value, the worse the compensation

Anion gap – anion difference

- The concentration of plasma anions that are not included in the list of routine biochemical analyzes.
- Normal - plasma proteins (10% of the total number of anions)? In pathology (met. Acidosis) - lactate, acetoacetate, sulfate, etc.
- AG = [Na +] - [Cl-] - [HCO3-]
- Norm - 8-16 mmol / l

When interpreting the result, it is necessary to exclude probable preanalytical and analytical errors and carry out an assessment in a specific clinical context.

taking into account data of the anamnesis.

If the result does not correspond to the clinical condition of the patient or is very different from the previous analysis, you may need to repeat the analysis before changing the treatment tactics.

Probable errors

- **preanalytical** - until the delivery of blood to the analyzer (the largest share of mistakes)
- **analytical** - directly related to the procedure of analysis in the apparatus, technical malfunction or inaccuracy of the apparatus, improper calibration, etc.
- **errors after taking a sample** - incorrect interpretation, assessment without taking into account the clinical status of the patient

Metabolic acidosis

- Diabetes
- Chronic renal failure
- Hyperthermia (as an isolated syndrome)
- Sepsis
- Acute infectious diseases
- Oncologic diseases of other conditions with increased catabrolism
- Rhabdomyolysis
- Renal acidosis
- Acid poisoning

Principles of correction of metabolic acidosis

- Emergency measures (ABC)
- Treatment of the cause is the most important !!!
- Replenishment of losses (for example, liquids and electrolytes)
- Specific treatment (introduction of ethanol in case of poisoning with methyl alcohol, alkalization of urine during rhabdomyolysis, etc.)

The formula for calculating the required amount of bicarbonate

$$D_{\text{bicarbonate required}} = 0,5 \times m \times [HCO_3]$$

Respiratory acidosis

- Acute and chronic hypoxic conditions (COPD, asthmatic status, drowning, suffocation, etc.)
- Violations of the ventilator protocol (hypoventilation)
- Acute Respiratory Distress Syndrome
- Pneumonia
- Thrombus
- Pulmonary edema
- Chest injuries
- Diseases manifested by cerebral edema
- Neuromuscular diseases
- Medical and narcotic intoxication

Metabolic alkalosis

- Pathological loss of hydrochloric acid (vomiting)

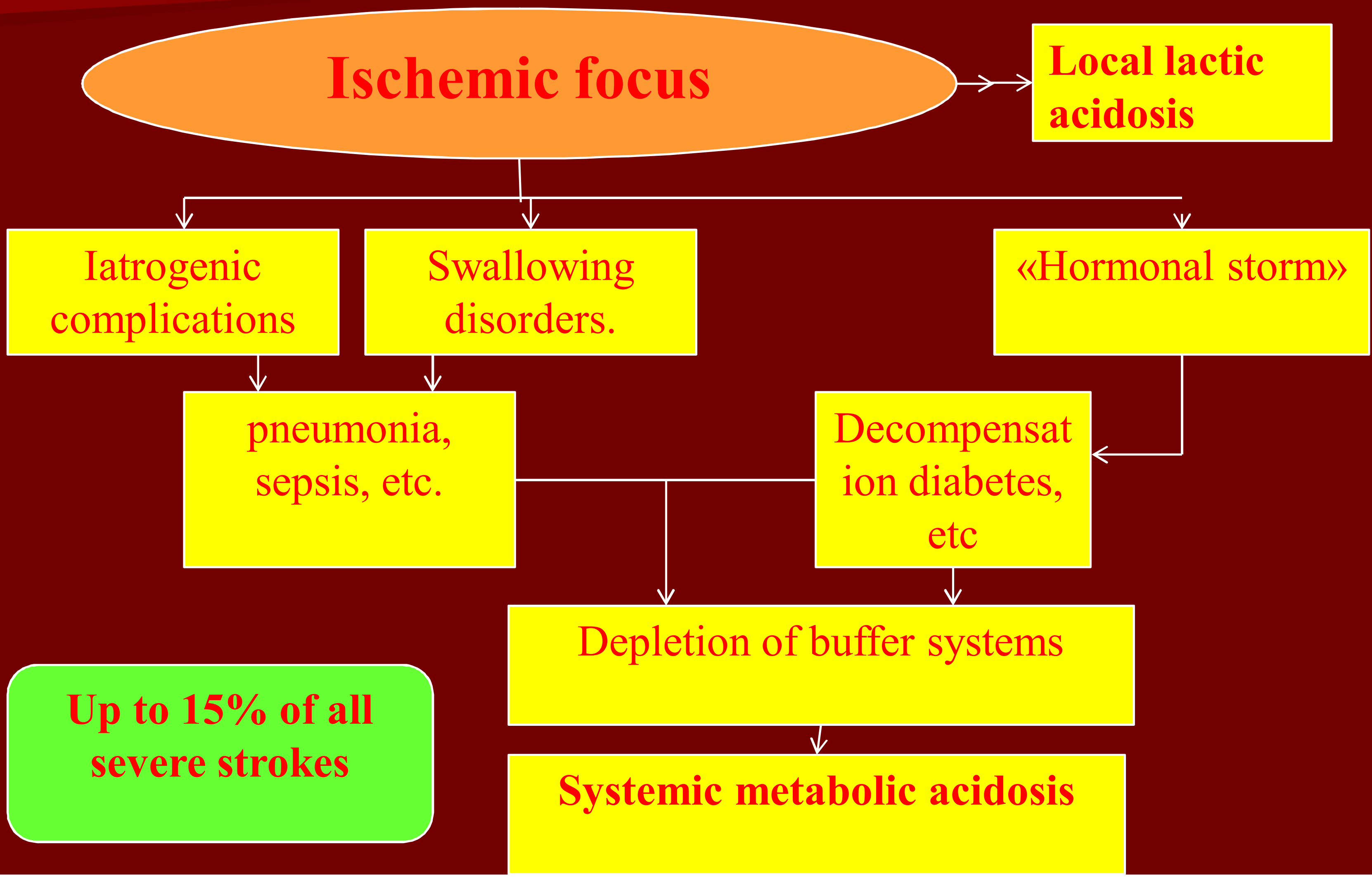
Respiratory alkalosis

- acute cerebrovascular accident and other damage to the central nervous system (with increased lung function)
- Violation of the protocol of ventilator (hyperventilation)
- Psychogenic hyperventilation
- Pain syndrome

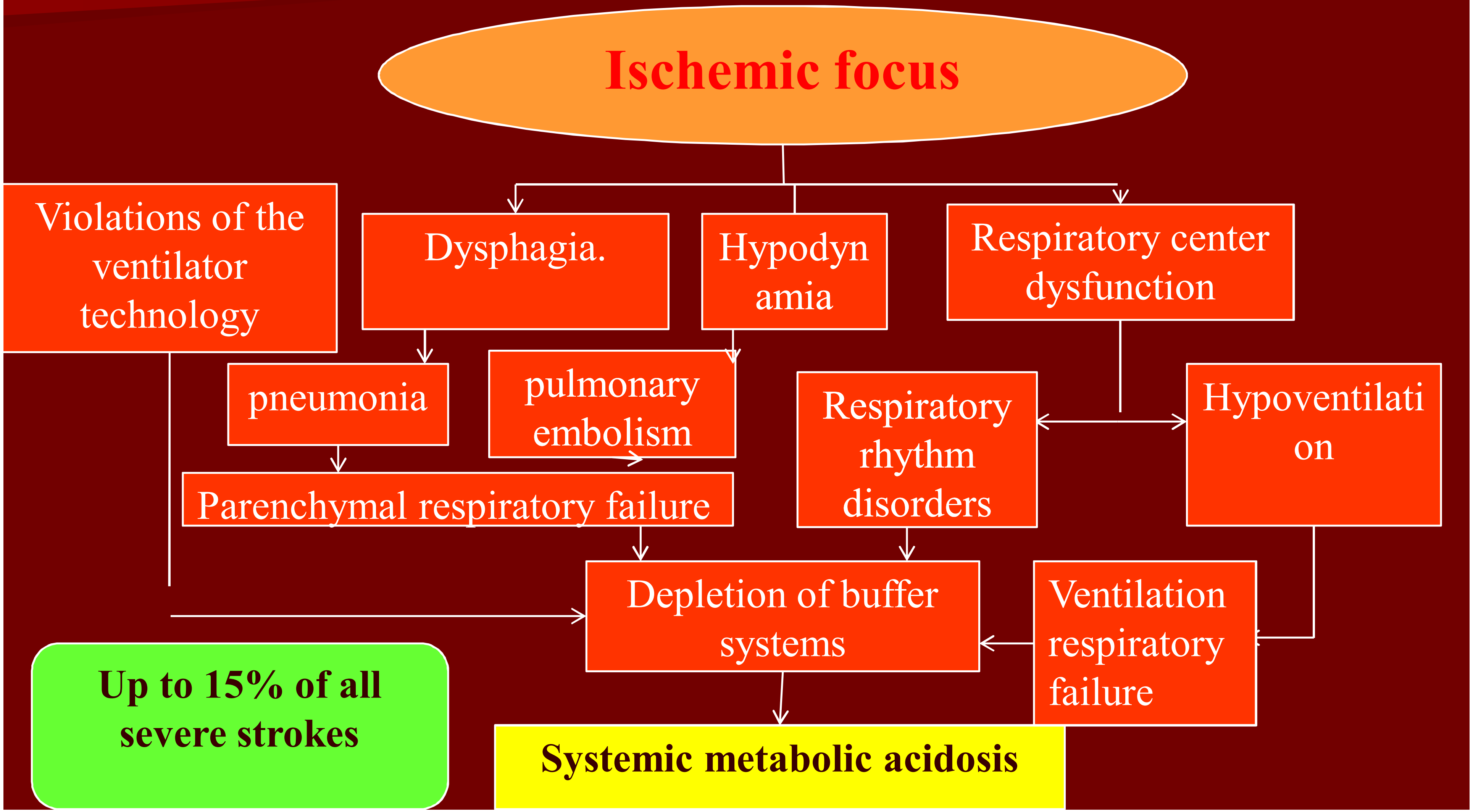
Disorders of acid-base balance in patients with stroke

- Metabolic acidosis
- Respiratory acidosis
- Metabolic alkalosis
- Respiratory alkalosis
- Combined and dissociated violations of CSR

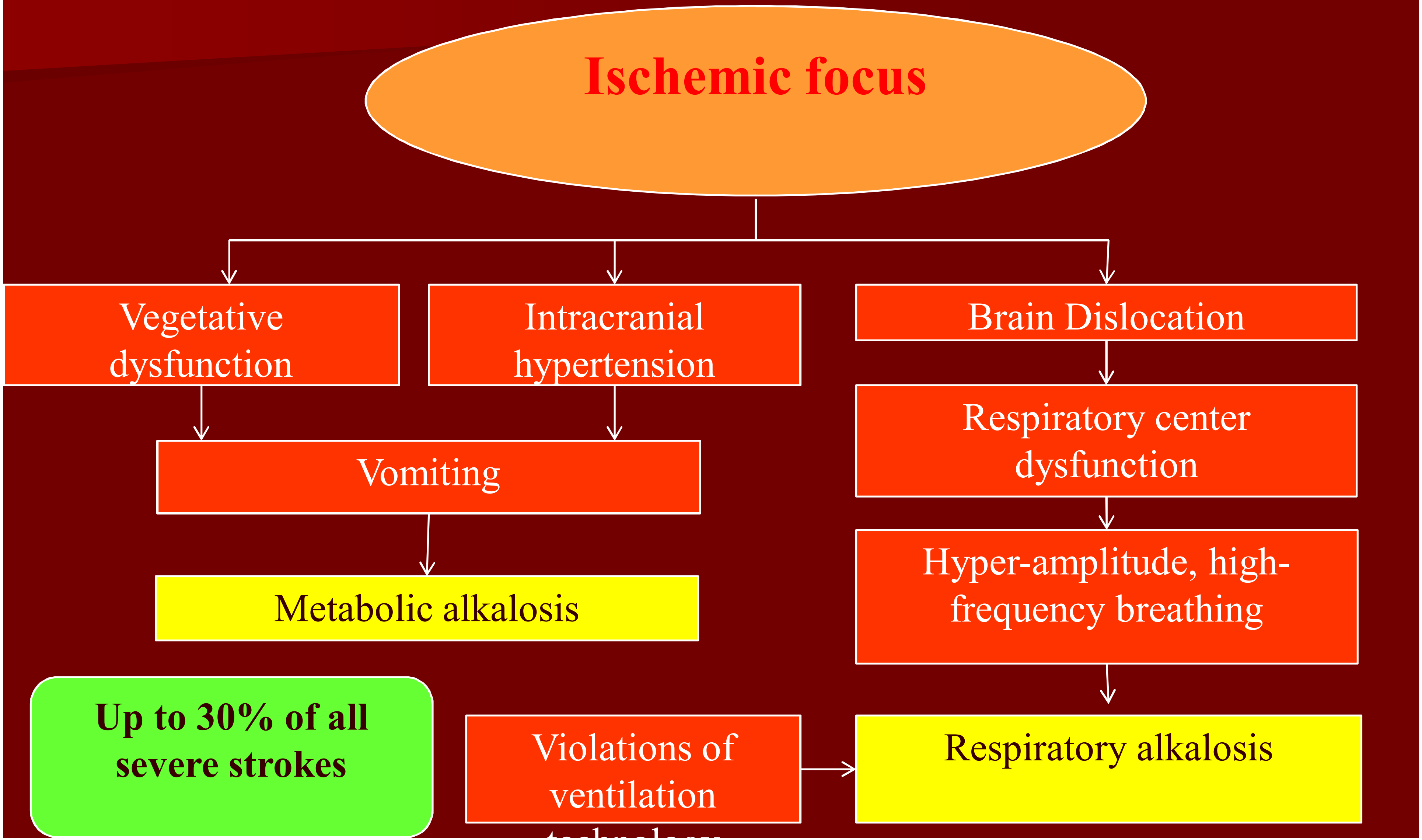
Metabolic acidosis in ischemic stroke



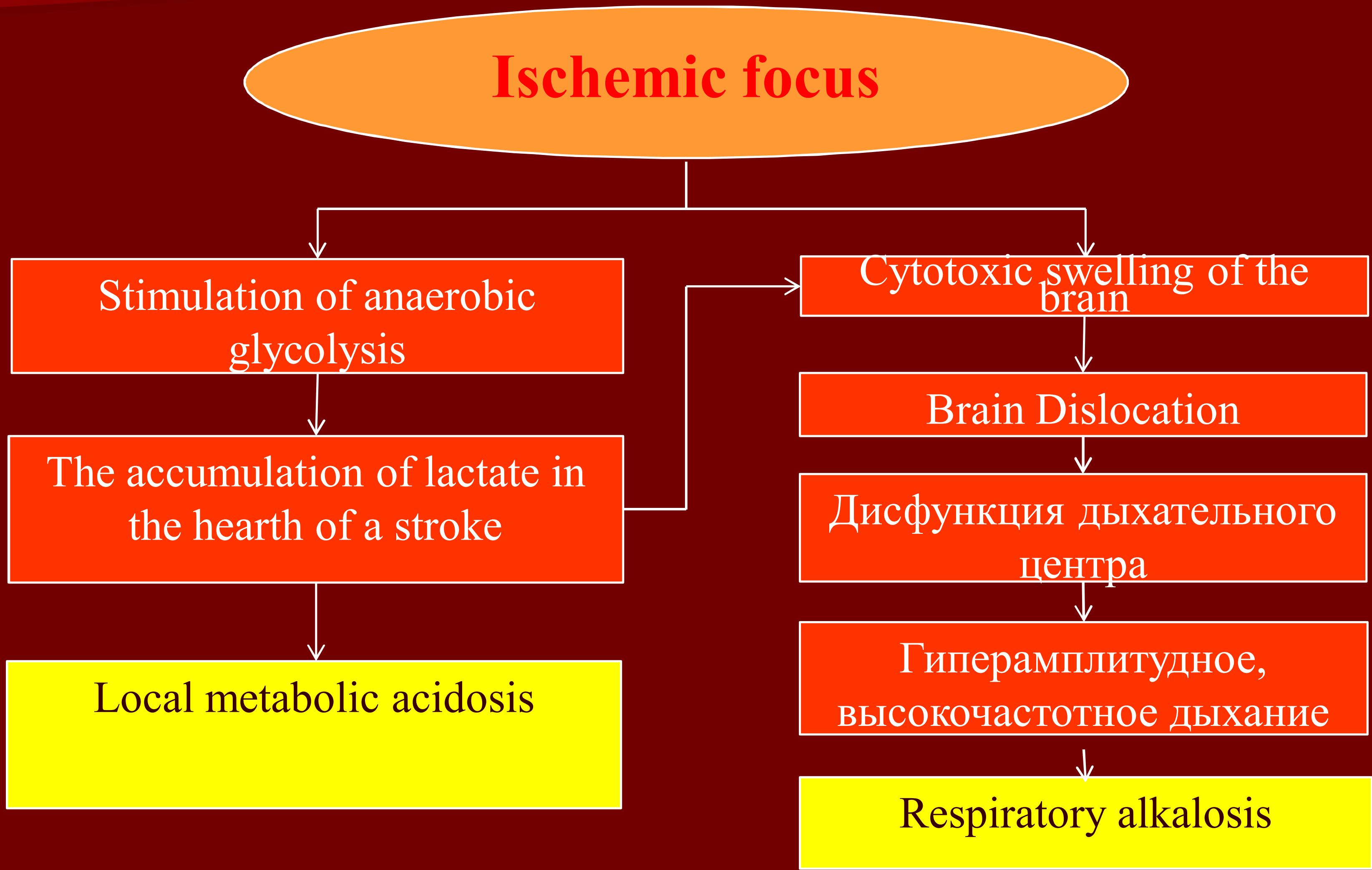
Respiratory Acidosis in Ischemic Stroke



Alkalosis in ischemic stroke



The mechanism of development of dissociating disorders of the acid-base state in stroke



The sequence of actions in the analysis of the parameters of the acid-base state

1.Estimate pH

Acidosis < (pH = 7.35 – 7.44) > Alkalosis

2.Identify the mechanism of impairment (respiratory or metabolic)

Is PaCO2 changed at changed pH?

If PaCO2 is reduced, 2 options are possible. :

- Primary frustration - respiratory character (respiratory alkalosis)
- pH and PaCO2 are changed in opposite directions.

pH = 7,55 (↑), PaCO2 = 22 mm Hg(↓)

If PaCO2 is reduced, there are 2 possible options:

- Primary Disorder - Metabolic Acidosis
- pH and PaCO2 changed in the same direction
- in this case, the decrease in PaCO2 is compensatory**pH = 7.18** (↓), **PaCO2 = 30.4 mm Hg**(↓),

BE = - 14.5 mmol\l

With an increased level of PaCO2, two options are also possible.

- The primary disorder is respiratory (respiratory acidosis, hypoventilation)
- pH and PaCO2 changed in opposite directions

pH = 7.26 (↓), PaCO2 = 48.2 mm Hg(↑)

With an increased level of PaCO2, two options are also possible.

- Primary Disorder - Metabolic Alkalosis
- pH and PaCO2 changed in the same direction

pH = 7.48 (↑), PaCO2 = 51 mm Hg(↑)

HCO3- = 30 mmol(↑)

3. Determine the stage of compensation

a) acute stage, compensation of primary changes has not yet occurred

pH is changed and one of the parameters (CO_2 or HCO_3^-) **pH = 7.23, $PaCO_2$ = 60 mm Hg, HCO_3^- = 24 ммоль/л (acute respiratory acidosis)**

B) ***subacute stage partial compensation stage***

the pH is changed, and the parameters (CO_2 and HCO_3^-) change in the same direction.

pH = 7.63, $PaCO_2$ = 14.6 mm Hg, HCO_3^- = 15.3 ммоль/л (partially compensated respiratory alkalosis)

C) ***chronic stage, full compensation stage***

The pH becomes close to normal (or N) with altered CO2 and HCO3– values.

pH = 7.44, PaCO2 = 21.2 mm Hg, HCO3- = 14.8 ммоль/л (compensated respiratory alkalosis) ***With metabolic acidosis, the concentration of HCO3 is always reduced, with metabolic alkalosis it is always increased, regardless of whether there is compensation or not.***

4. Simple or mixed violation

Isolated disorders of acid-base states in clinical practice almost never occur.

The response to metabolic disorders develops very quickly, if the compensation mechanisms are not violated, for example, during mechanical ventilation.

In acute cases, metabolic alkalosis is compensated worse than acidosis.

The following ratios of values are characteristic of mixed CBS violations:

with a shift of pH towards acidosis and an increased level of PaCO2, the concentration of bicarbonate is not increased (as one would expect when compensating for respiratory acidosis), and decreased - mixed acidosis

pH – 7.11, PaCO2 – 53 mm Hg, HCO3- = 16 mmol\L

For mixed violations of acid - base states, the following ratios of values are characteristic:

with an increase in pH and a reduced level of $PaCO_2$, the concentration of bicarbonate is not reduced (as with the compensation of respiratory alkalosis), and the mixed alkalosis is increased

pH = 7.51, $PaCO_2$ = 33 mm Hg, HCO_3^- = 29 mmol\L

If the pH and PaCO2 are changed in the same direction and the pH is different from the norm - the primary metabolic disorder

pH = 7.32 (↓), PaCO2 = 34 mm Hg(↓)

When pH and pCO2 change in opposite directions, primary disorder -

respiratory

pH = 7.23 (↓), PaCO2 = 60 mm Hg(↑)

Classification of blood gas disorders

[Boyda E, Kee J, Monaghan F. 1994]

Classification	pH	*PaCO2*	HCO_3^-
Respiratory disorders			
Uncompensated acidosis	↓	↑	N
Partially compensated acidosis	↓	↑	↑
Compensated acidosis	N	↑	↑
Uncompensated alkalosis	↑	↓	N
Partially compensated alkalosis	↑	↓	↓
Compensated alkalosis	N	↓	↓
Metabolic disorders			
Uncompensated acidosis	↓	N	↓
Partially compensated acidosis	↓	↓	↓
Compensated acidosis	N	↓	↓
Uncompensated alkalosis	↑	N	↑
Partially compensated alkalosis	↑	↑	↑
Compensated alkalosis	N	↑	↑
Mixed offense			
Mixed acidosis	↓	↑	↓
Mixed alkalosis	↑	↓	↑

5. Amendment to laboratory error

If the results do not correspond to the clinical condition of the patient, you should probably:

- -eliminate errors associated with the analysis;
- -eliminate possible errors associated with storage, transportation or dilution of the sample;
- -calibrate the device;
- -repeat the analysis.

Thank you for attention!