# Pathophysiology of water and ion metabolism

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# Sudden disaster on a Sunday afternoon .....

- 84 years old female, admitted to hospital 12 days earlier because she had had diarrhoea for 3 days
- On admission she looked volume depleted, had low BP (90/50 mmHg)
- Laboratory results: Hgb 9,86 g%, serum Na 134 mmol/l, K 3,0 mmol/l, BUN 21,9 mmol/l, creatinine 182 umol/l
- She got 0,9% NaCl infusion+KCl for 3 days
  the BP normalized (118/59 mmHg),
  the labs: Na 141 mmol/l, K 3,6 mmol/l, BUN 4,1 mmol/l, creatinine 86 umol/l
- The gastroenterology team decided to go on with GI work up in order to look for the cause of anemia

# Sudden disaster on a Sunday afternoon .....

- Scheduled for colonoscopy on Monday (plan to preparing her by Fleet enema on Sunday evening)
- Instruction by the nurse on Sunday morning: „no solid food to eat, only fluids to drink”
- On Sunday morning – complaints free, ambulating, „looked nervous”
- In the afternoon: she suddenly lost her consciousness, had a convulsion, did not respond even to pain, had uncoordinated movements in all her extremities. Repeatedly vomited.

# Sudden disaster on a Sunday afternoon .....

- Urgent labwork: serum Na 117 mmol/l, K 2,9 mmol/l, BUN 2,4 mmol/l, cretinine 98 umol/l
- Urinary osmolality 431 mOsm/kg, urinary Na 164 mmol/l, K 44 mmol/l hrs, 900 ml/12 hrs
- Brain CT:
  -no major abnormality can be seen
- She remained unconscious in the next day:
  Neurological examination:
  - no primary neurological abnormality,
  EEG: diffuse functional cortical abnormality

# Sudden disaster on a Sunday afternoon .....

- Why was she mildly hyponatremic on admission?
- Why had she severe hyponatremia 12 days later?
- What do you think about the urinary osmolality of 431 mOsm/kg?
- And about the urinary Na of 164 mmol/l?
- What is your suggestion for treatment on the day of admission?
- What would you give on the 12th day? How much?

# Hyponatremia

**ADH secretion + Water intake**

Both need to be present

**Why ???**

Why is ADH secreted in spite of hypoosmolality?

Where is the water coming from?

**Is this an acute or a chronic condition?**

# ADH secretion

- In physiologic conditions
  - increased osmolaltity
  - increased serum Na

- In pathophysiologic conditions
  - stress, anxiety, pain, fever, nausea, vomiting
  - severe hypovolemia due to
    - fluid loss
    - diuretic use
  - effective volume depletion
  - SIADH
  - medications

# Treatment on the first day

- The major stimulus for ADH was the volume depletion
- 0,9 % NaCl infusion shuts off the stimulus for ADH secretion
- How do you know this?
  The urine with high osmolality (evidence for ADH secretion) changes to less concentrated urine
  → the patient becomes able to excrete free water
  → the low serum osmolality and low serum Na are increasing and get normalized
- Hypertonic Na infusion is unnecessary and dangerous

# Treatment on the 12th day

- Acute, severe hyponatremia, causing convulsion, coma, vomiting → very likely cerebral edema
- Urine osmolality: 431 mOsm/kg means - strong influence of ADH
- Urine Na: 164 mmol/l means - no volume depletion
- Treatment: 3% NaCl infusion
- How much?

# Treatment on the 12th day

- Weight of the patient: 72 kg. Body water: 42 l
  In order to elevate her serum Na by 1 mmol/l, she needs 42 mmol Na
  In order to elevate serum her Na by 5 mmol/l, she needs 210 mmol Na
  It means 408 ml of 3% NaCl infusion
- Follow urinary Na loss and replace it
- Check electrolytes frequently

# Treatment on the 12th day

- She got 300 ml 3% NaCl infusion (154 mmol) and 4 g KCl
- 4 hours later serum Na 119 mmol/l, K 3,2 mmol/l
- During Sunday night 300 ml 3% NaCl infusion (154 mmol) and 4 g KCl
- On Monday morning 300 ml 3% NaCl infusion (154 mmol)
- In 24 hours: serum Na 130 mmol/l, K 3,9 mmol/l
- Urinary losses in 24 hrs: 230 mmol Na and 62 mmol K
- In summary she got 462 mmol Na in the 1$^{st}$ 24 hrs
- Next day: serum Na 134 mmol/l, she regained consciousness
- Two days later: serum Na 140 mmol/l

# Acute hyponatremia

**ADH secretion + Water intake**

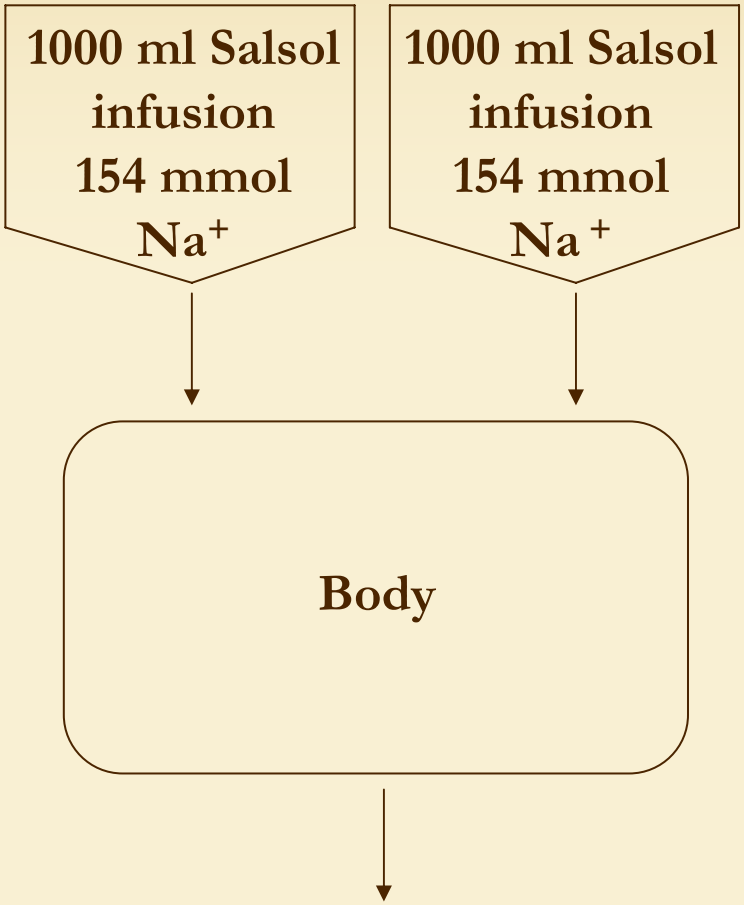
**Both need to be present**

**Why ???**

Why is ADH secreted in spite of hypoosmolality?
- stress, anxiety, pain, fever, nausea, vomiting,
typically in a perioperative situation

Where is the water coming from?
- hypotonic fluid intake, very often iv. infusions

# Generation of EFW - Desalination




**Balance:**

**Water intake: 2000 ml**
**$Na^+$ intake 308 mmol**
**Excreted free water: 1000 ml**
**Excreted $Na^+$: 308 mmol**

**No reason to retain NaCl**

**Persistent ADH action: 1 L electrolyte free water is retained in the body, which causes hyponatremia**

# More tests than thoughts....

- 69 yrs female,  in her past medical history:
  - 1990. Resection of malignant lung tumor
  - For 2 years hypertension, osteoporosis
  - Meds: indapamide, aspirin, carvedilol, vitamin D, Calcium suppl.
- 2008. october
  - dizziness, headache, unsteadiness, repeated falls
  - Once she invited guests, treated them, made conversation, but later did not remember these events
- SeNa  oct. 3.  141,  dec.19.  126,
  oct.29.  119,  febr.20. 120 mmol/l.
  nov.17. 124,

# More tests than thoughts....

- Tests because of her complaints (oct-febr):
  - head CT, 2x head MRI, neurosurgical consultation (some traumatic contusions)
  - chest XR and CT, mammography, abdominal US, carotid art. doppler scan, neurological examination
- Modification of the therapy:
  - Indapamide changed to ramipril+hydrochlorothiazide
  - Increased salt and fluid (!) intake suggested (although the patient did not whish to drink much)

- **What is wrong with this lady?**

# Not so difficult....

- Febr. 20. Nephrology consultation: discontinue the thiazide, continue increased salt intake but limit fluid intake
- March 10. Free of complaints - SeNa 140 mmol/l.

# The most frequent causes of hyponatremia

*Clayton et al. Q.J.Med 2006*

- Hyponatremia was found in 108 of the 9622 patients admitted to internal medicine department in 6 months
- Etiology
  - **Thiazide diuretics** - 29 cases
    („Thiazides: do they kill?" P.Gross, C.Palm, NDT 2005)
  - **Congestive heart failure -** 27 cases
  - **Liver cirrhosis** - 21 cases
  - In further cases: volume depletion, medications, malignancies, lung- and cerebral diseases, hypothyroidism, Addison disease, hypoNa postoperatively, primary polydipsia and chronic renal failure
- During the hospitalization 20% of the patients died

# Risk factors for thiazid-induced hyponatremia

*Chow et al. Q.J. Med 2003*

- Between 1996-2002 223 thiazide caused hyponatremic patients were observed
- SeNa: 98-128 mmol/l (mean 116±7 mmol/l)
- Average length of treatment 1-4479 day! (mean 105 day)
  - 42,8% indapamide,
  - 16,1% HCT,
  - 17,3% HCT+amiloride,
  - 15,4% HCT+triamterene
  - 8,4% bendrofluazide
- Thiazides were administered mainly for hypertension
- Risk factors for developing hyponatremia:
  age, low body weight, hypokalemia

# Pathomechanism of thiazid-induced hyponatremia

- In most cases ADH secretion could not be explained by volume depletion!
- When thiazide is taken, the medulla can achieve high concentration – little ADH is enough to produce concentrated urine
- Decreased urinary dilution capacity in the elderly
- Increased fluid intake due to increased thirstiness (?)
- Decreased salt intake –adviced medically sec.to HTN (?)
- $Na^+$-$K^+$ transcellular shift in hypokalemia
- Activation of AQP-2 channels in cortical tubules due to thiazides – individual sensitivity (?)

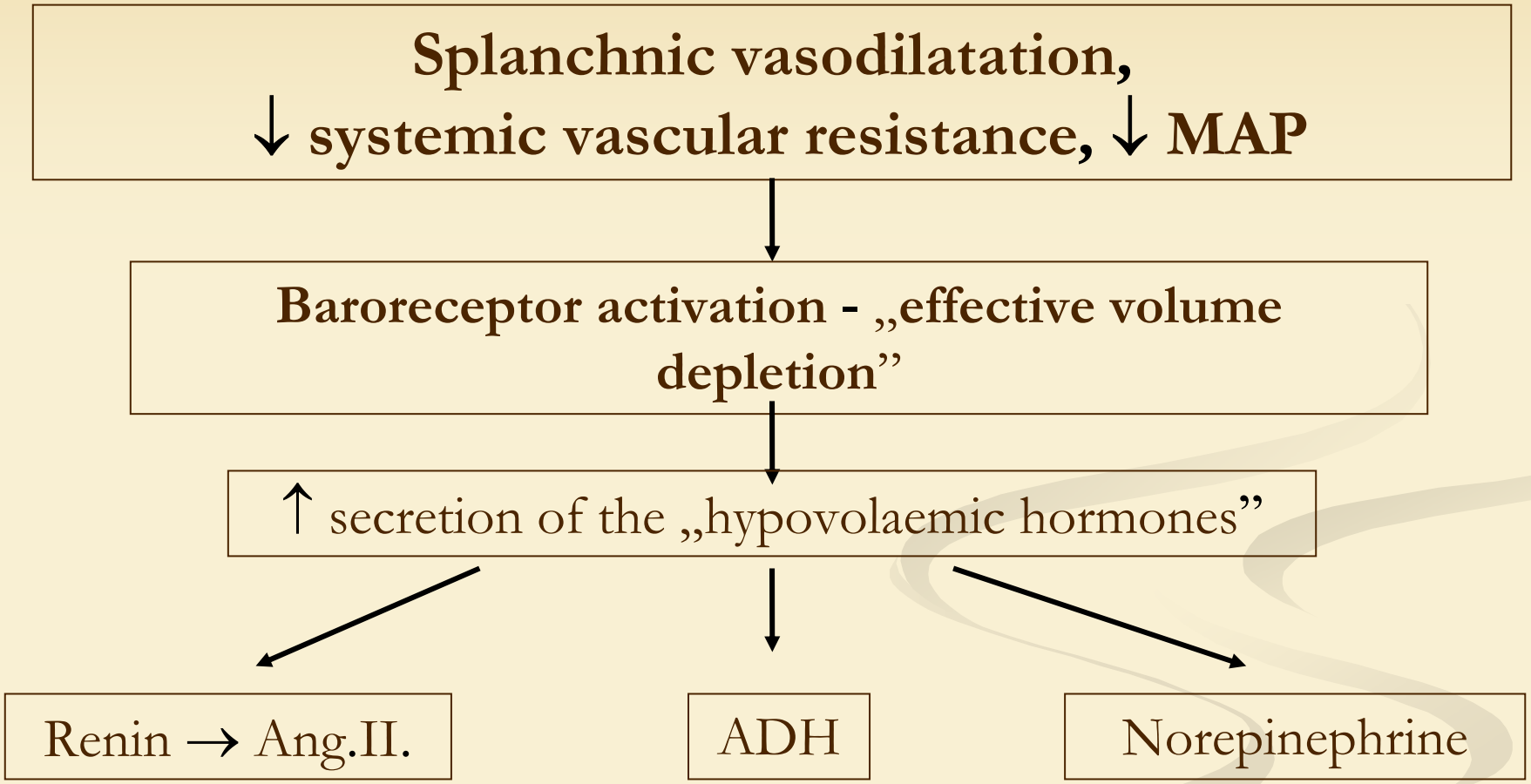
# Do cirrhotic patients need sodium in hyponatremia?

- 70 yrs old male, treated on an internal medicine department He is a regular alcohol drinker, has liver cirrhosis, oedema on the legs and huge ascites
- On admission: serum Na 132 mmol/l, K 4,2 mmol/l, BUN 5,7 mmol/l, creatinine 82 umol/l
- Initial treatment: 100 mg spironolactone, 160 mg furosemide, 50 mg ethacrynic acid, 50 mg hydrochlorothiazide, 3 g KCl
- In three days BW 115 → 111 kg, Na 132 → 125 mmol/l, creatinine 82 → 126 umol/l
- Treatment: furosemide discontinued, others continued, + 5 g NaCl in Ringer infusion

# Do cirrhotic patients need sodium in hyponatremia?

- In the nex three days: BW → 120 kg, SeNa → 117 → 109 mmol/l, creatinine → 270 umol/l,
- Even more NaCl given
- Consultation asked for nephrology service because oliguria, deteriorating renal functions:
  SeNa 112 mmol/l, K 3,8 mmol/l, BUN 8,8 mmol/l, creatinine 307 umol/l
  Urinary Na excretion 2 mmol/day, K 8,6 mmol/day
- **How would you manage this patient?**

# Hyponatremia in cirrhotic patients

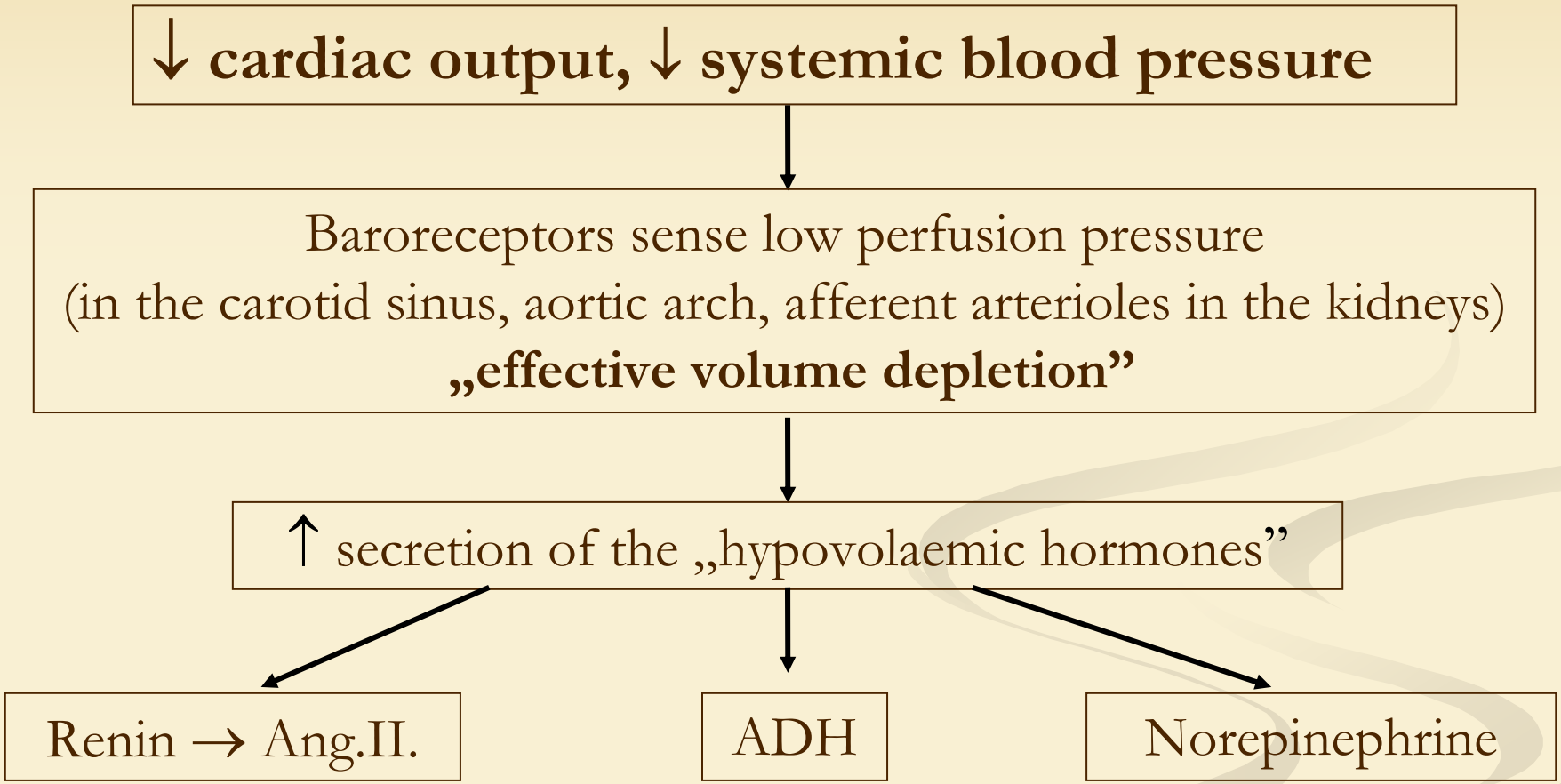



Other factors causing hyponatremia:

-overgenerous diuretic treatment

-too much fluid intake (e.g. Beer drinkers)

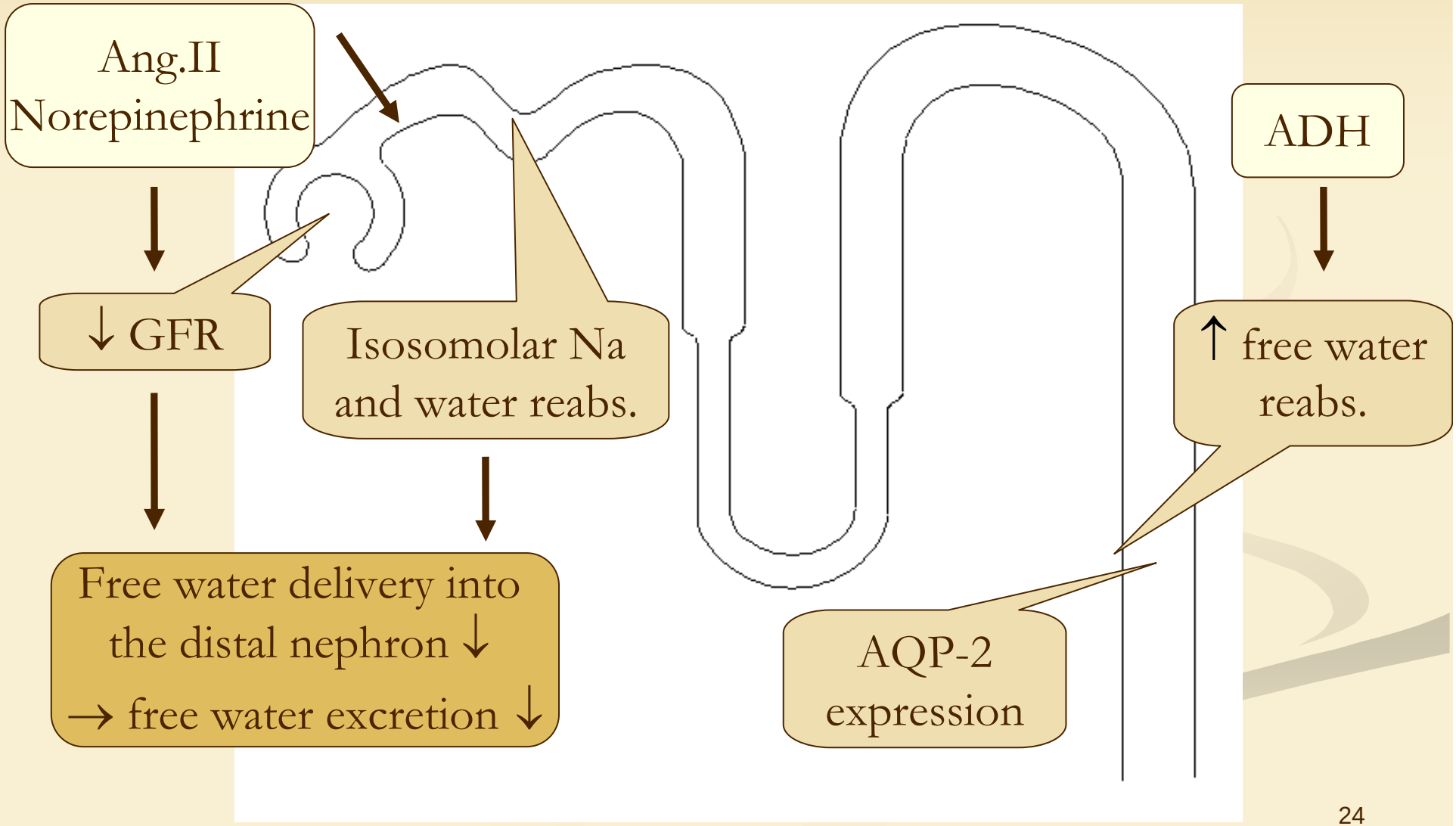
# Hyponatremia in congestive heart failure




Other factors causing hyponatremia:

Low cardiac output, high level of Ang II. → increased thirstiness

# Disturbed free water clearance – effects of the „ hypovolaemic hormones”



# Hyponatremia in cirrhotic patients

- Severity of hyponatremia is proportional to the prognosis
- Correction of hyponatremia does not change the hemodynamical, pathophysiological abnormalities
- Mild hyponatremia usually does not cause any complaints, do not have to be treated (≈>125mmol/l)
- Treatment: decrease fluid intake in order to achive negative fluid balance
- „Delicate" diuretic administration, mainly loop diuretics (if peripheral edema present, ↓ BW: by 1-2 kg/d, if only ascites: <0,5 kg/d)
- Hypertonic saline infusion is contraindicated !!
- Vasopressin receptor antagonists: aquaretics (vaptans)

# Therapy in CHF

- Survival is proportional to the degree of hyponatremia
- Its correction does not improve the prognosis of CHF
- ACEI/ARB
  - Cardiac output improves
  - ACEI decreases ADH's effectivity in the cortical collecting duct, therefore water reabsorption ↓
  - Decreased thirstiness
- Moderate fluid restriction
- Administration of moderate doses of loop diuretics
- Vasopressin receptor antagonists: aquaretics (vaptans)

# A case of SIADH

- 66 years old male, ALL diagnosed 9 months ago
- Got monthy bolus cytostatic treatments
- Developed aspergillus pneumonia - Rx intaconazole
- Admitted secondary to feeling unwell, weak, dizzy, but he was ambulating, can properly communicate
- Labs: Na 117 mmol/l, K 3,5 mmol/l, Cl 85 mmol/l, bicarb 23 mmol/l, BUN 6,5 mmol/l, creatinine 75 umol/l, BS 8,3 mmol/l, serum osmolality 237 mOsm/kg, urinary Na 83 mmol/l, osmolality 456 mOsm/kg, normal TSH
- According to his chart: serum Na 123-133 mmol/l previously
- **Why does he have ADH? Acute or chronic?**

# Chronic hyponatremia

**ADH secretion + Water intake**

Both need to be present

**Why ???**

Why is ADH secreted in spite of hypoosmolality?
- hypovolemia due to fluid loss, diuretic use, effective volume depletion, SIADH, medications

Where is the water coming from?
-usually not extraordinarily huge fluid intake

# Inappropriate ADH secretion - SIADH

- Malignancies
  - small lung cell carcinoma
  - prostate, uterus cc.
  - pancreas, duodenum cc.
  - leukemia, lymphoma

- Central nervous syst.dis.
  - Tumors, abscess
  - infections
  - Demyelinization diseases
  - SAH, trauma

- Medications
  - dDAVP, oxytocin, NSAID
  - antidepressants,
  - narcotics, nicotine
  - cytostatics
  - chlorpropamide
  - carbamazepine

- Lung diseases
  - TBC, aspergillosis
  - pneumonia, abscess
  - obstructive lung disease
  - ventillation

# Vaptans

- Vasopressin receptor antagonists – increase electrolyte-free water excretion
- Conivaptan (V1a and V2), tolvaptan, satavaptan, lixivaptan (V2 receptor antagonists)
- Indicated (in general) in euvolemic and hypervolemic hyponatremia
- Contraindicated in hypovolemic hyponatremia
- Overcorrection of hyponatremia has to be avoided!
- Very expensive drugs

# Tolvaptan – EVEREST trial

## Gheorghiade M et al., JAMA 2007. 297:1332

- Short and long term administration of tolvaptan
  - randomised controlled trial
  - 4133 patients admitted with chronic heart failure
- Body weight, dyspnea, edema ↓, serum Na ↑ more in patients who received tolvaptan
- But no effect on mortality, comparing to placebo
- Mental functioning showed small but significant improvement in the tolvaptan group

# Tolvaptan – SALT1 and SALT2 trials
## Schrier RW et al. NEJM 2006. 355:2099

- Two multicenter RCTs for 30 days
- Tolvaptan 225 pts, placebo 223 pts with SIADH, CHF, and cirrhosis
- Serum Na increased more in the tolvaptan group
- Hyponatremia recurred after tolvaptan was discontinued
- Patients in the tolvaptan group had increased thirst, dry mouth, increased urination

# Hyponatremia in chronic renal failure

- Our case: 72 years old lady, regularly seen on clinic
  - eGFR 10 ml/min
  - Nausea, vomiting, feeling unwell
  - Se Na 129 mmol/l, urine output 3400 ml/day
- On the next visit:
  - Se Na 135 mmol/l
  - urinary osmolality 284 mOsm/kg
  - urine output 2800 ml/day
- **Why was she hyponatremic?**

# What does the maximal urinary diluting capacity mean?

- Healthy persons:
  - Minimal urine osmolality: 50-80 mOsm/kg
  - Average solute excretion: 600-900 mOsm/day (300-450 mmol Na, K + the anions, and 300-450 urea)
- How much can we drink without the risk of hyponatremia?

  Solute excretion / diluting capacity / L
  - 900 mOsm and 50 mOsm /kg = 18 L
  - 600 mOsm and 80 mOsm /kg = 7,5 L
  - 200 mOsm and 50 mOsm /kg = 4 L
- Beer potomania („Tea and toast" hyponatremia):
  - Low protein and salt intake, therefore low osmolar excretion and too much fluid intake

# Hyponatremia in chronic renal failure

- The urine is „isostenuric” ≈ 300 mOsm/kg
- The kidneys are not able to dilute significantly better (nor concentrate)
- If the daily solute excretion 900 mOsm – maximally 3 L fuid can be excreted, without causing hyponatremia
- But on low protein and low salt diet the daily solute excretion ↓, therefore exaggerated fluid intake can cause hyponatremia
- Therapy: adjust fluid intake to the actual diluting capacity of the kidneys

# What kind of i.v. infusion has to be given in hypernatremia?

- 81 yrs old male patient, admitted to hospital because of volume depletion and pneumonia. He was febrile, desoriented.
- Lab results: serum Na 156 mmol/l, K 5,0 mmol/l, BUN 22 mmol/l, creatinine 173 umol/l, glucose 6,1 mmol/l.
- Chest XR: pneumonia and pulmonary congestion
- Initial treatment: 500 ml of Ringer lactate infusion and 500 ml 5% glucose infusion
- **Was this appropriate? What kind of change do you expect in serum Na concentration?**

# What kind of i.v. infusion has to be given in hypernatremia?

- Next morning:

  - Serum Na 157 mmol/l, osmolality 330 mOsm/kg
  - Urinary Na 40 mmol/l, K 48 mmol/l,
    osmolality 463 mOsm/kg

  (24 hrs collection could not be done)

# What kind of i.v. infusion has to be given in hypernatremia?

- Na balance

  - the patient excreted 40 mmol/l sodium,
  - intake by RL: 67 mmol
  (Ringer lactate contains 132 mmol/l)

- Treatment on the following day

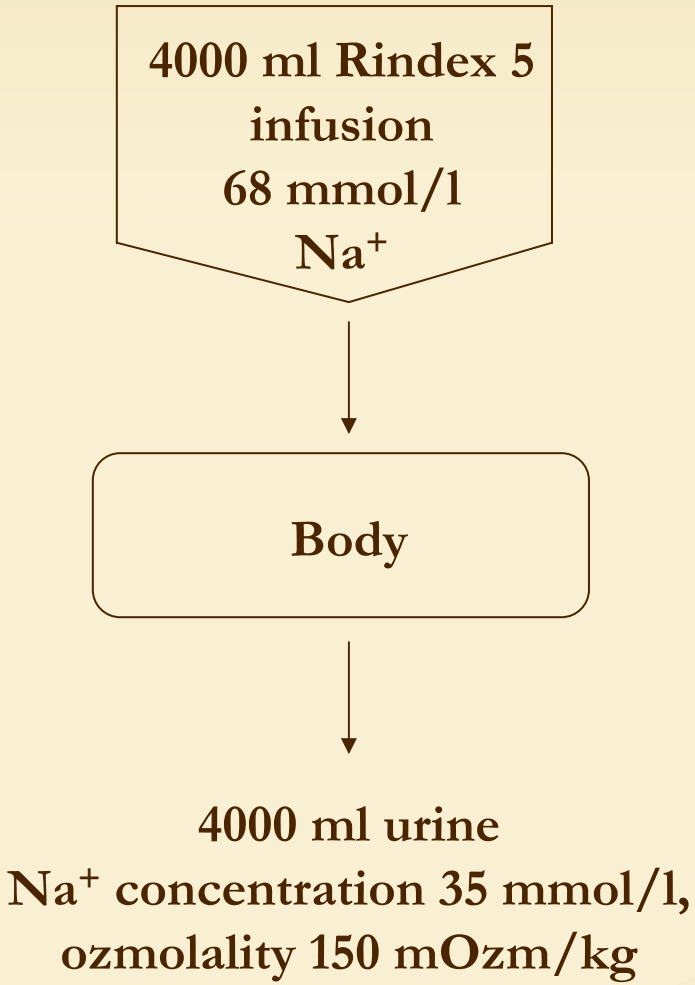
  1500 ml 5% glucose infusion, and he was eating and drinking a litte
  Serum Na 159 mmol/l

- **Why? What can we do now?**

# What kind of i.v. infusion has to be given in hypernatremia?

- Checking again the urinary excretion:
  Na 11 mmol/l, K 9,5 mmol/l osmolality 439 mOsm/kg
- He was excreting very little Na
- He was not able to increase his urine osmolality
- We gave 40 mg furosemide i.v. and 2500 ml 5% glucose infusion daily
- The urinary Na excretion increased to 52 mmol/l, K excretion to 30,2 mmol/l
- The serum Na decreased gradually and in 3 days normalized to 137 mmol/l

# Sodium balance in diabetes insipidus




**Balance:**

**Water intake: 4000 ml/24 hr**
**$Na^+$ intake 272 mmol**
**Excreted water: 4000 ml/24 hr**
**Excreted $Na^+$: 140 mmol/24 hr**

**The patients retains 33 mmol $Na^+$ by each L of infusion**
**In 24 hours 132 mmol $Na^+$ surplus created in the body.**

# Hypokalemia – where does this huge amount of K go?

- A 62 yrs old female
- PMHx: collagen colitis – she had been well for years
- She presented with profuse, watery diarrhoea, several times daily. In the last days nausea and vomiting also occurred
- On admission: severly volume depleted, very weak, completely anuric, BP 60/40 mmHg.

# Hypokalemia – where does this huge amount of K go?

- Labs on admission:
  Na 124 mmol/l, K 1,8 mmol/l, BUN 31,5 mmol/l, creatinine 665 umol/l

| Days | KCl g/day | HD-Dialysate K | Serum K | |
|---|---|---|---|---|
| 1 | 4 | 3 mmol/l | 1,5 | anuric |
| 2 | 14 | 3 mmol/l | 2,3 | anuric |
| 3 | 12 | - | 2,6 | oliguric |
| 4 | 14 | - | 3,0 | diuresis |
| 5 | 14 | - | 3,6 | diuresis |
| 6 | 10 | - | 3,8 | diuresis |

# Hypokalemia – where does this huge amount of K go?

- **Why did she need so much K?**
  (83 g = 1079 mmol)
- **Did this patient have renal K wasting tubulopathy?**

# Hypokalemia – first step in differential diagnosis

- Urinary K excretion
  - In our patient: 19,5 mmol/day
    18,8 mmol/day
- TTKG – transtubular K gradient

$$\frac{\text{Urine K}}{\text{Serum K}} \quad X \quad \frac{\text{Serum osmolality}}{\text{Urine osmolality}}$$

- In our patient: 4,9

# Hypokalemia – where does this huge amount of K go?

- Body weight of the patient: 60 kg
  Extracellular water: 10 l
  Intracellular water: 20 l
- K content of EC: 10x4= 40 mmol
  K content of IC:  20x150=3000 mmol

# An other hypokalemic patient ...

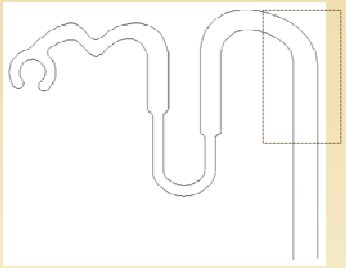
- 48 years old male
- PMHx: hypertension since his age of 30
- His mother, his sister and his son also have HTN
- Serum potassium between 2,5-2,8 mmol/l for years
- Meds on the first consultation: 20 mg amlodipin, 2x20 mg enalapril+hydrochlorothiazide, 4 mg prasosin, 2x2 g KCL
- Labs: serum Na 145 mmol/l, K 2,9 mmol/l, CN 7,7 mmol/l, creatinine 100 umol/l
- **What kind of tests would you order?**

# An other hypokalemic patient ...

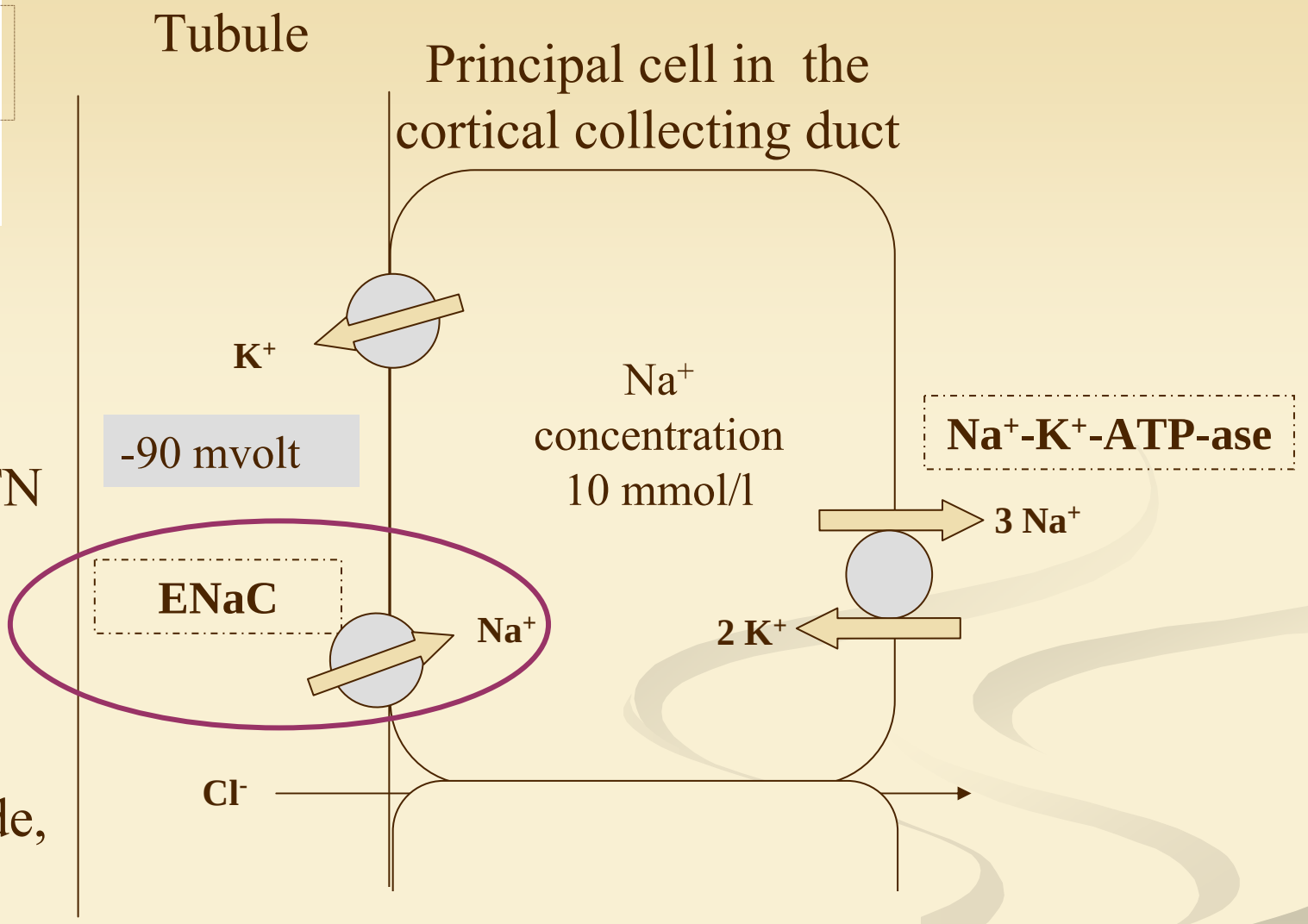
- 24 hr urinary Na: 262 mmol/day
  24 hr urinary K: 104 mmol/day
  urinary osmolality: 678 mOsm/kg
- TTKG 15,8
- **What is the differencial diagnosis?**

# An other hypokalemic patient ...

- Renin and aldosterone levels: repeatedly normal
- RAS, glucocorticoid overproduction excluded
- Rx: spironolactone – no change
- **What is your diagnosis and how would you treat this patient?**

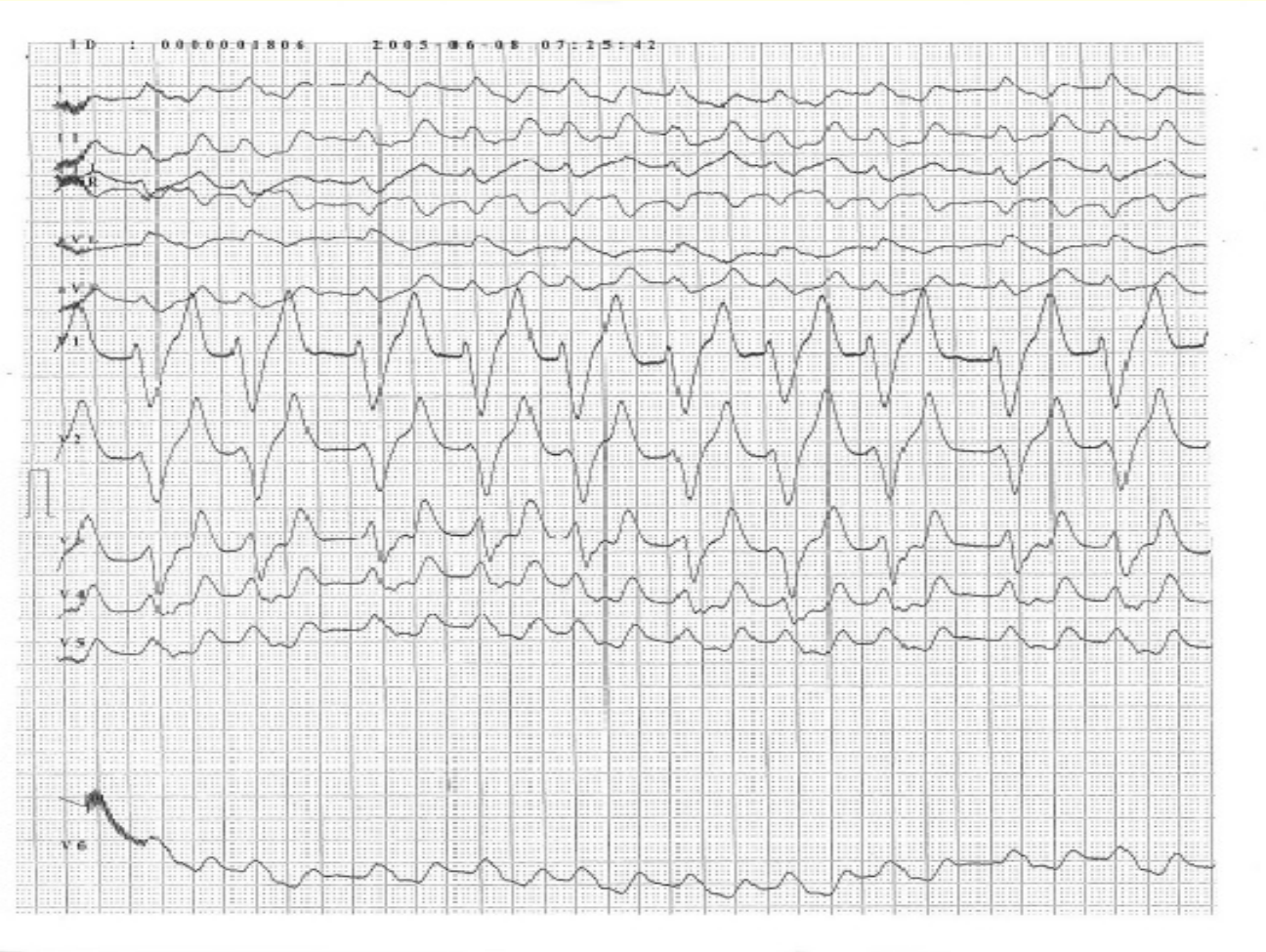


- Continually open ENaC
- Familiar HTN
- Suppressed renin and aldosterone
- Rx: amiloride, triamterene




# Liddle syndrome

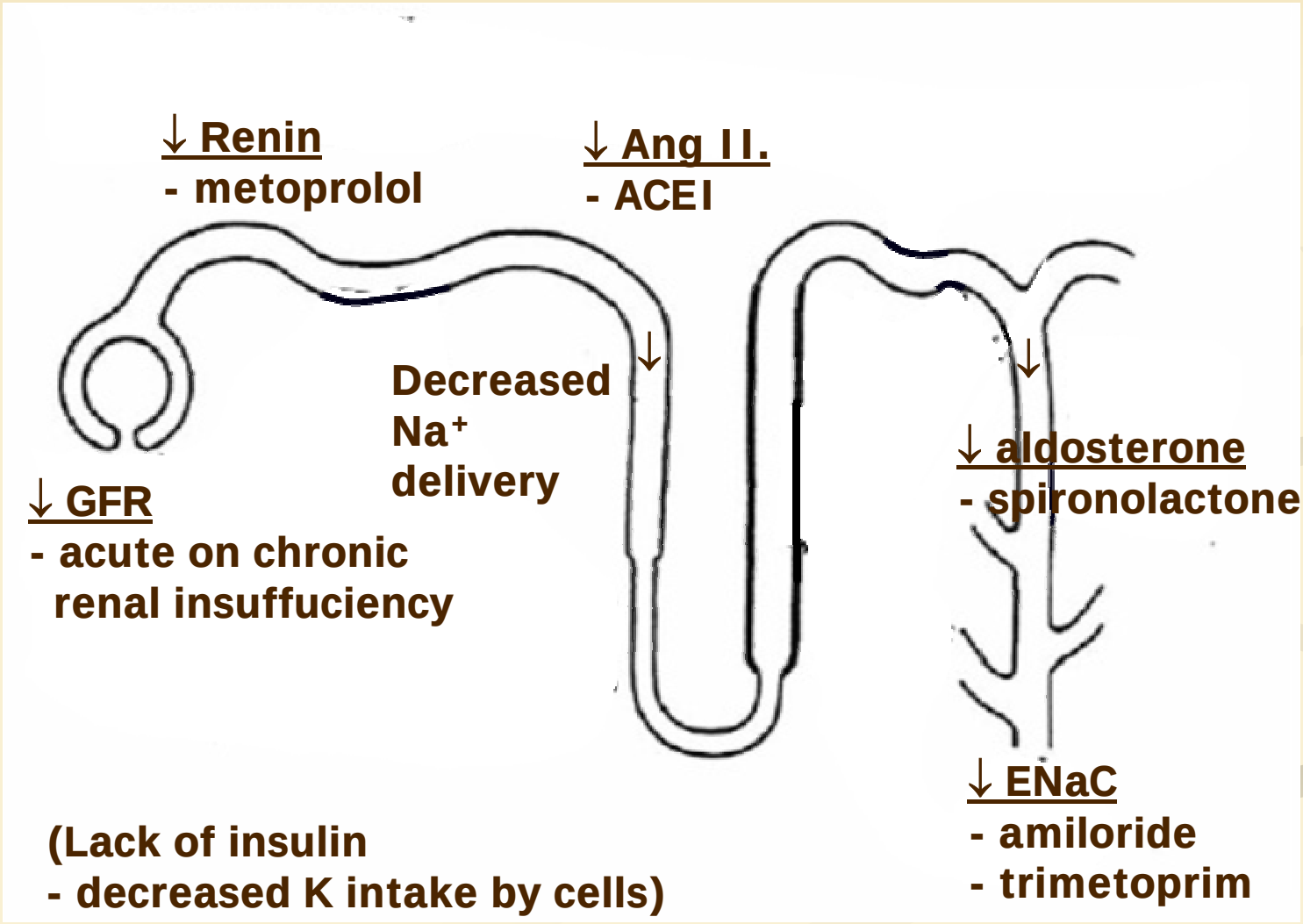
# Is this an emergency?



# Life threatening hyperkalemia

- 82 years old female with HTN, DM, and CRF
- Serum creatinin earlier 150 umol/l
- Rx: 20 mg lisinopril, 20 mg spironolactone, 5 mg amiloride, 50 mg hydrochlorotiazide, 100 mg metoprolol, trimetroprim-sulfamethoxasol for one week
- Extremely week, unable to walk, than respiratory insufficiency developed
- Labs: serum Na 133 mmol/l, K 10,0 mmol/l, Cl 102 mmol/l, HCO3 18 mmol/l, kreat 265 umol/l, CN 31,5 mmol/l, Vc 26,4 mmol/l, urinary K 16 mmol/l.
- **How many reasons did she have for hyperkalemia?**

# Inhibitors of renal potassium excretion



# Acid-base disorders

# A bicarbonate of 2.3 mmol/l

- 78 yrs old male
  -PMHx: diabetes mellitus, hypertension
  -admission in very poor condition: desoriented, Kussmaul-breeding, BP 88/52 mmHg, oligo-anuric
- Serum Na 139 mmol/l, K 5,8 mmol/l, Cl 99 mmol/l
  BUN 39 mmol/l, creatinine 504 umol/l,
  bicarb 2,3 mmol/l
- **What should we do?**

# A bicarbonate of 2.3 mmol/l

- Blood-gas analysis:
  pH 6,97
  $HCO_3^-$ 2,3 mmol/l
  $pCO_2$ 10,2 mmHg

- **What kind of acid-base disorder is this?**

# A bicarbonate of 2.3 mmol/l

- Decrease in bicarbonate
  25-2,3 = 22,7 mmol/l
- Respiratory compensation: delta pCO2
  40 - $pCO_2$ = 40-10,2 = 29,8 mmHg
- Anion gap
  $Na^+$-($Cl^-$+$HCO_3^-$)=139-(99+2,3)= 37,7 mmol/l

# A bicarbonate of 2.3 mmol/l

- The patient has:
  - high anion gap metabolic acidosis
- His lactate level:
  - 12,2 mmol/l
- He was taking metformin, which caused lactic acidosis
- He was dialysed, survived, but remained dialysis dependent

# Types of anion gap acidosis

**Gain of acids**

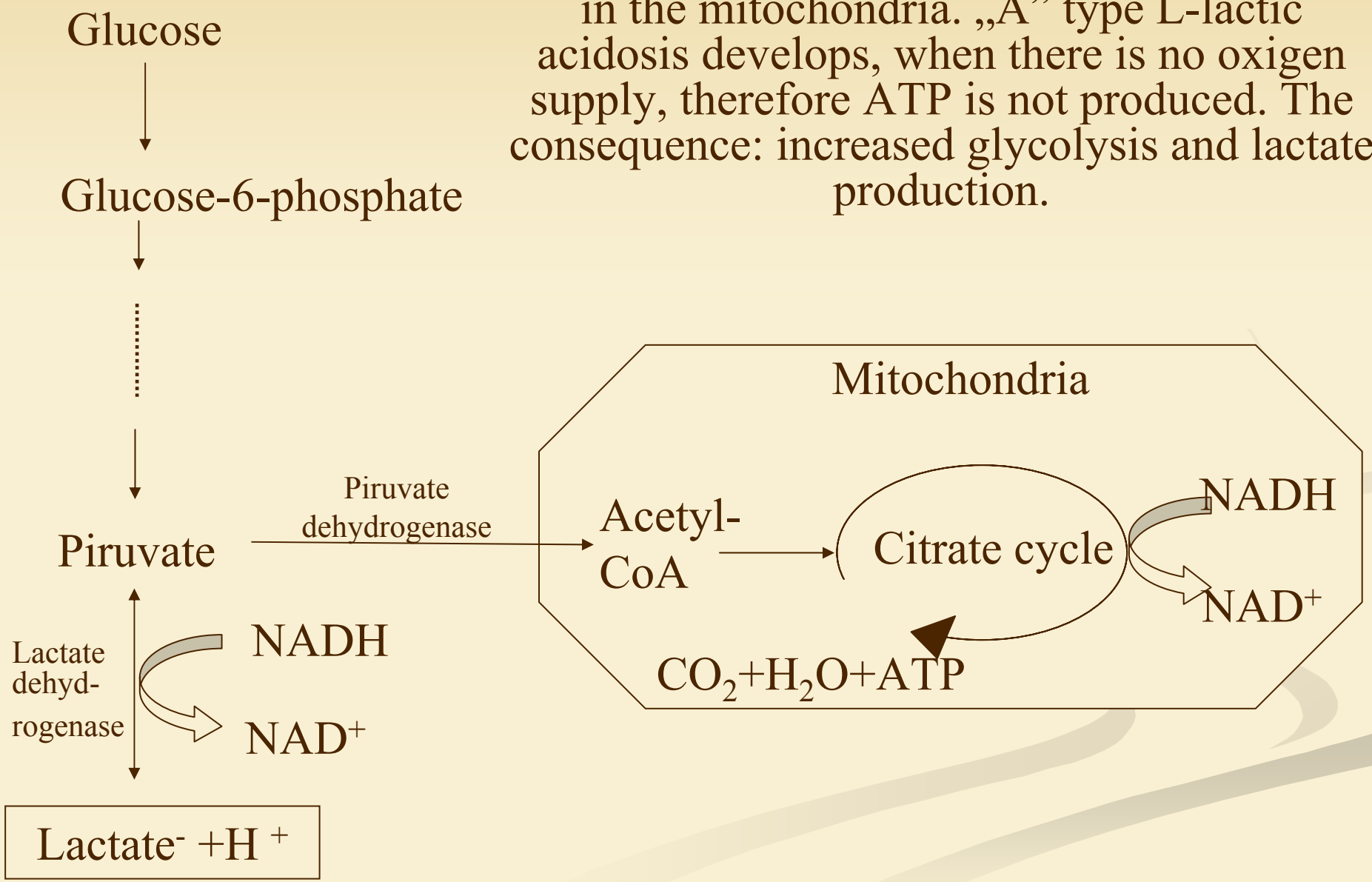
**Endogenous acid production**

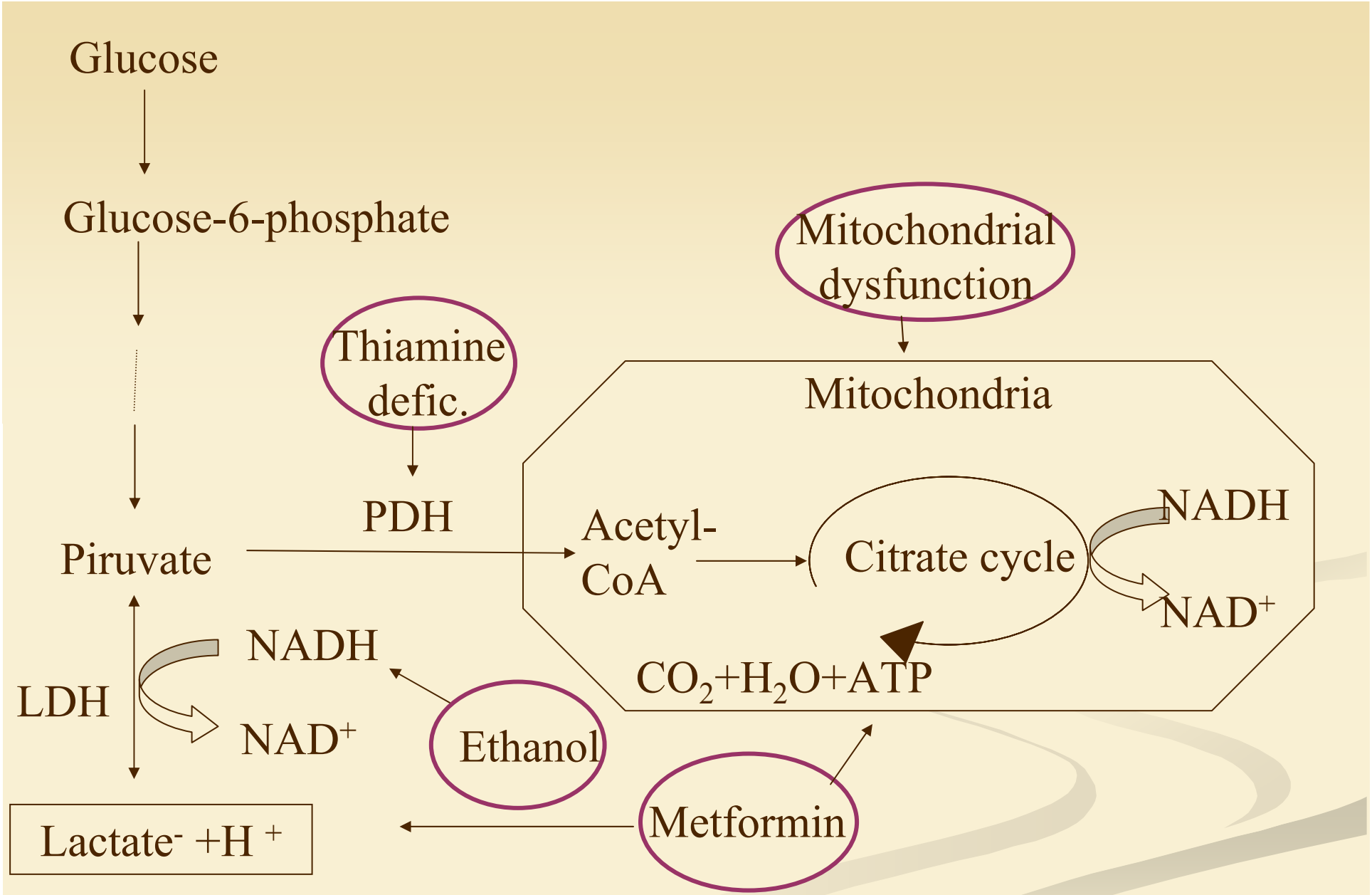
- ketoacidosis
-L-lactic acidosis (A and B-types)
- D-lactic acidosis
- advanced renal failure

**Exogenous acids**

-ethylene glycol
-methanol

Oxygen is necessary for the ATP production in the mitochondria. „A” type L-lactic acidosis develops, when there is no oxigen supply, therefore ATP is not produced. The consequence: increased glycolysis and lactate production.






**The most frequent causes of „B" type L-lactic acidosis**

# Deteriorating pH

- A 42 yrs old male patient consulted by nephrology service
- He was admitted to the hospital secondary to rapidly deteriorating physical condition the previous day
- Medical Hx: joint problems, hip replacement, on NSAIDs, aethyl abusus
- Labs on admission:
  -Serum Na 138 mmol/l, K 2,9 mmol/l, Cl 121 mmol/l, BUN 24,8 mmol/l, creatinine 432 umol/l, Hgb 9,6 g%
  -Blood gas analysis: pH 7,29, bicarbonate 10,8 mmol/l, pCO2 14,2 mmHg
- Gastroscopy revealed bleeding from gastric ulcers
- **What kind of acid-base disorder is this?**

# Deteriorating pH

- Decrease in bicarbonate
  25-10,8 = 14,2 mmol/l
- delta pCO2
  40 - $pCO_2$ = 40-14,2 = 25,8 mmHg
- Anion gap
  $Na^+$-($Cl^-$+$HCO_3^-$)=138-(121+10,8)= 6,2 mmol/l

# Deteriorating pH

- Treatment: he got proton pump inhibitor, Na-bicarbonate infusion and furosemide, but did not improve
- Blood gas analysis few hours later:
  pH 7,19, bicarb 9,1 mmol/l, pCO2 24,3 mmHg
  (previous: pH 7,29, bicarb 10,8 mmol/l, pCO2 14,2 Hgmm)
- **What happend to the pH?**

# Deteriorating pH

- Next day:
  pH 6,84 bicarb 9,7, pCO2 57,6 mmHg
  (previous: pH 7,29, bicarb 10,8 mmol/l, pCO2 14,2 Hgmm
  pH 7,19, bicarb 9,1 mmol/l, pCO2 24,3 mmHg)
- **What kind of acid-base disorder is this now?**

# Acidosis

## pH ↓

$HCO_3^-$ ↓

metabolic acidosis

↓

$pCO_2$ ↓

respiratory compensation

**1:1**

$pCO_2$ ↑

respiratory acidosis

↓

$HCO3^-$ ↑

metabolic compensation

**1:0,3**

# Alkalosis
## pH ↑

HCO3- ↑
metabolic alkalosis

↓

pCO2 ↑
respiratory compensation

**1:0,7**

$pCO_2$ ↓
respiratory alkalosis

↓

HCO3- ↓
metabolic compensation

**1:0,5**

# A complicate case

- 33 yrs old male patient
- PMHx: ileocecal reticulosarcoma, ileum and colon resection, irradiation colitis, moderate chronic renal failure, recently proved distal renal tubular acidosis
- Medical Hx: has usually 3-4 bowel movements/day
  Had several GI tests performed recently, and severe, watery diarrhoea developed
  Admitted in a very poor condition, severly volume depleted
- Labs: Serum Na 142 mmol/l, K 2,99 mmol/l, Cl 119 mmol/l, BUN 7,6 mmol/l, creatinine 224 umol/l,
- Blood gas analysis: pH 7,19, bicarb 12,0 mmol/l, pCO2 32 mmHg

# A complicate case

- What kind of acid-base disorder is this?
- Why is he hypokalemic?

# A complicate case

- Combined metabolic and respiratory acidosis
  -delta bicarbonate: 25 - 12 = 13 mmol/l
  -delta pCO2: 40 - 32 = 8 mmHg
- Anion gap: 142-(119+12) = 9
  (lactate level 1,03 mmol/l)
- Urinary K excretion 9,9 mmol/l
  - non-renal K loss
- **Is this acidosis due to gastrointestinal bicarbonate loss or renal abnormality?**

# Differential diagnosis of non-anion gap metabolic acidosis

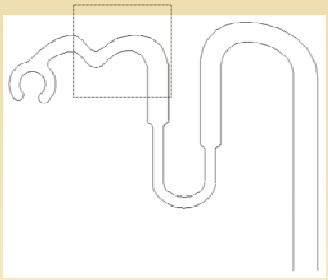
**Low plasma bicarbonate level**

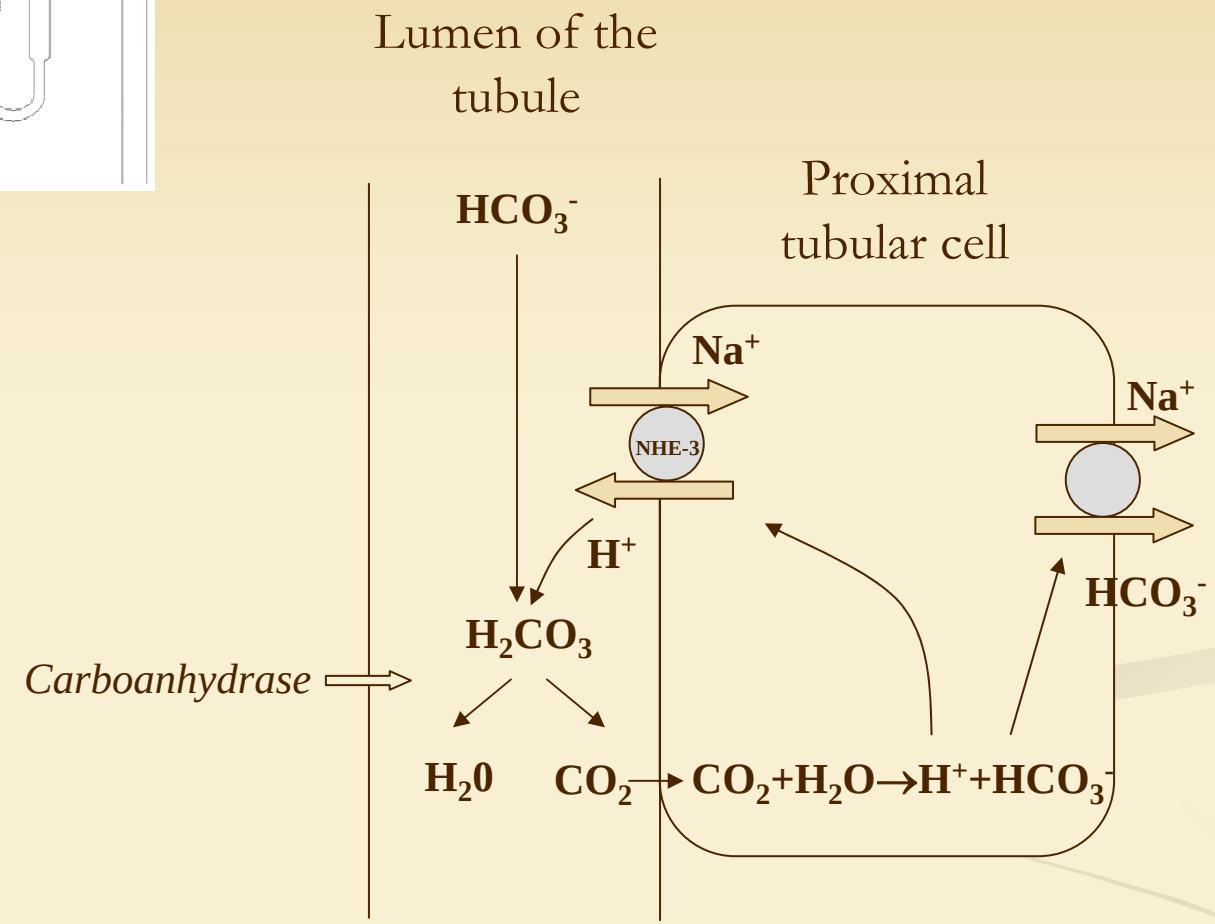
**Gastrointestinal bicarbonate loss**

Urine $Cl^-$ >> $Na^+ + K^+$
(refers to $NH_4^-$ production)

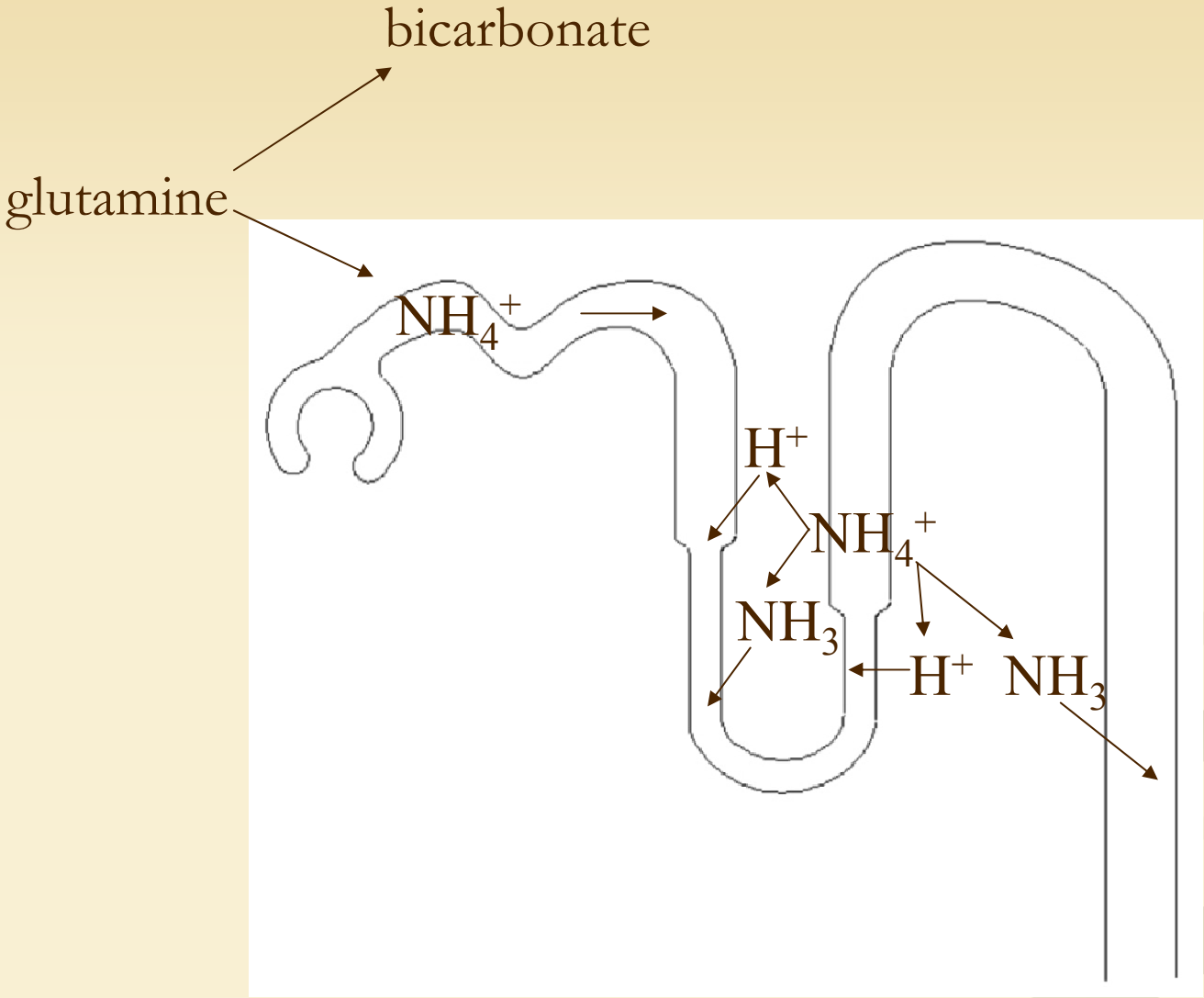
**Renal tubular abnormality**

-pRTA
-insufficient $NH_4^+$ production
-dRTA

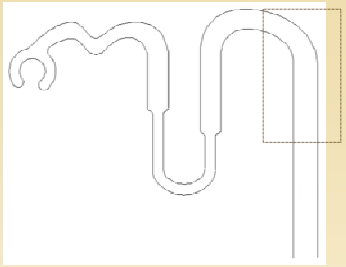


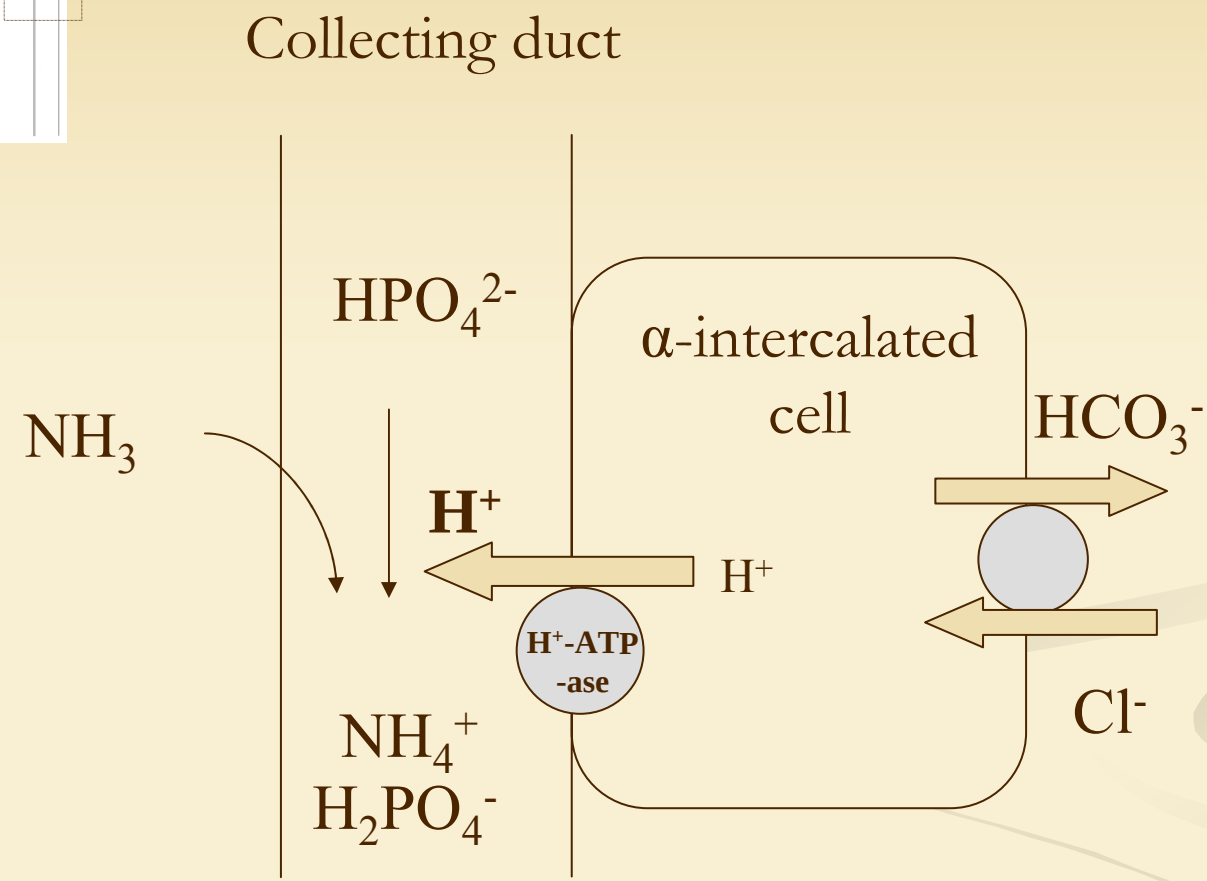



Physiologic bicarbonate reabsorption in the proximal tubule. pRTA develops due to reduced indirect bicarbonate reabsorption.




Bicarbonate-ammonia production is necessary for $H^+$ excretion






dRTA develops if the $H^+$ secretion is disturbed in the collecting duct

# Gastrointestinal disease diagnosed by blood pH

- A 41 year-old male patient, admitted to hospital secondary to nausea, vomiting and epigastric pain
- On admission he looked severly volume depleted, had a BP of 96/58 mmHg
- Labs: serum Na 123 mmol/l, K 3,5 mmol/l, BUN 24 mmol/l, creatinine 355 umol/l,
- Blood gas analysis: pH 7,65, bicarb 43 mmol/l, pCO2 55,2 mmHg.
- **What is your diagnosis?**

# Gastrointestinal disease diagnosed by blood pH

- Metabolic alkalosis, hyponatremia and hypokalemia, acute renal failure
- According to the clinical picture – suspicion of pylorus stenosis
- Gastroscopy confirmed this abnormality (ulcer causing pylorus stenosis)
- Therapy: 0.9 % NaCl infusion, KCl replacement, PPI
- Labs one week later: serum Na 143 mmol/l, K 5,1 mmol/l, CN 9,5 mmol/l, creatinine 128 umol/l, pH 7,39, bicarb 24,8 mmol/l, pCO2 44 mmHg.