Breakthrough Electrolytes Abnormalities

for internists

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Case 1:

A 30-year-old woman with underlying HIV disease is brought to ER for fatigue and poor appetite. Her current medications include TDF/3TC/EFV, Bactrim and folic acid. She is afebrile, her blood pressure is 110/70 mmHg, pulse rate of 95 beats/min. The physical examination appears normal.

LAB:

- Na 136 mmol/L K 2.0 mmol/L Cl 115 mmol/L HCO_3 15 mmol/L
- BUN 15 mg/dL Cr 0.52 mg/dL
- ABG: pH 7.25 pCO_2 30 paO_2 98 HCO_3 9
- UA: pH 7, glucose neg, Alb neg, wbc 0-1, rbc 0-1
- U_{Na} 50 mmol/L, U_K 50 mmol/L, U_{Cl} 60 mmol/L, U_{Glu} 54 mg/dL, U_{urea} 28 mg/dL
- U_{osm} 300 mOsm/kg

What is the **MOST** likely cause of her symptoms ?

A. Sjogren syndrome B. TDF

C. Bactrim D. Chronic diarrhea

HYPOkalemia (K < 3.5 mmol/L)

Pseudohypokalemia

- ↑**WBCs** (> 100,000/mm^3) eg. AML

Transcellular shift

- **Insulin**
- **ß$_2$-agonist**
- Refeeding syndrome
- **Periodic paralysis** (Thyrotoxicosis, Familial)
- Theophylline, Chloroquine

HYPOkalemia (K < 3.5 mmol/L)

TTKG < 2

↑Tubular flow → Osmotic diuresis

Extrarenal K⁺ loss

Metabolic **ACIDOSIS**	**NORMAL** acid-base	Metabolic **ALKALOSIS**
• Diarrhea (Lower GI)	• Profuse sweating	• Vomiting (Upper GI)

Renal K⁺ loss

- Spot UK > 15 mmol/L
- 24h UK > 20 mmol/day
- UK/UCr > 1.5 mEq/mmolCr
- UK/UCr > 13 mEq/gCr

Renal K⁺ loss

TTKG > 4

HT + Metabolic **ALKALOSIS**

↑PAC, ↓PRA
- 1º Aldosteronism
- GRA

↑PAC, ↑PRA
- Renal a. Stenosis
- Renin secreting tumor
- Malignant HT

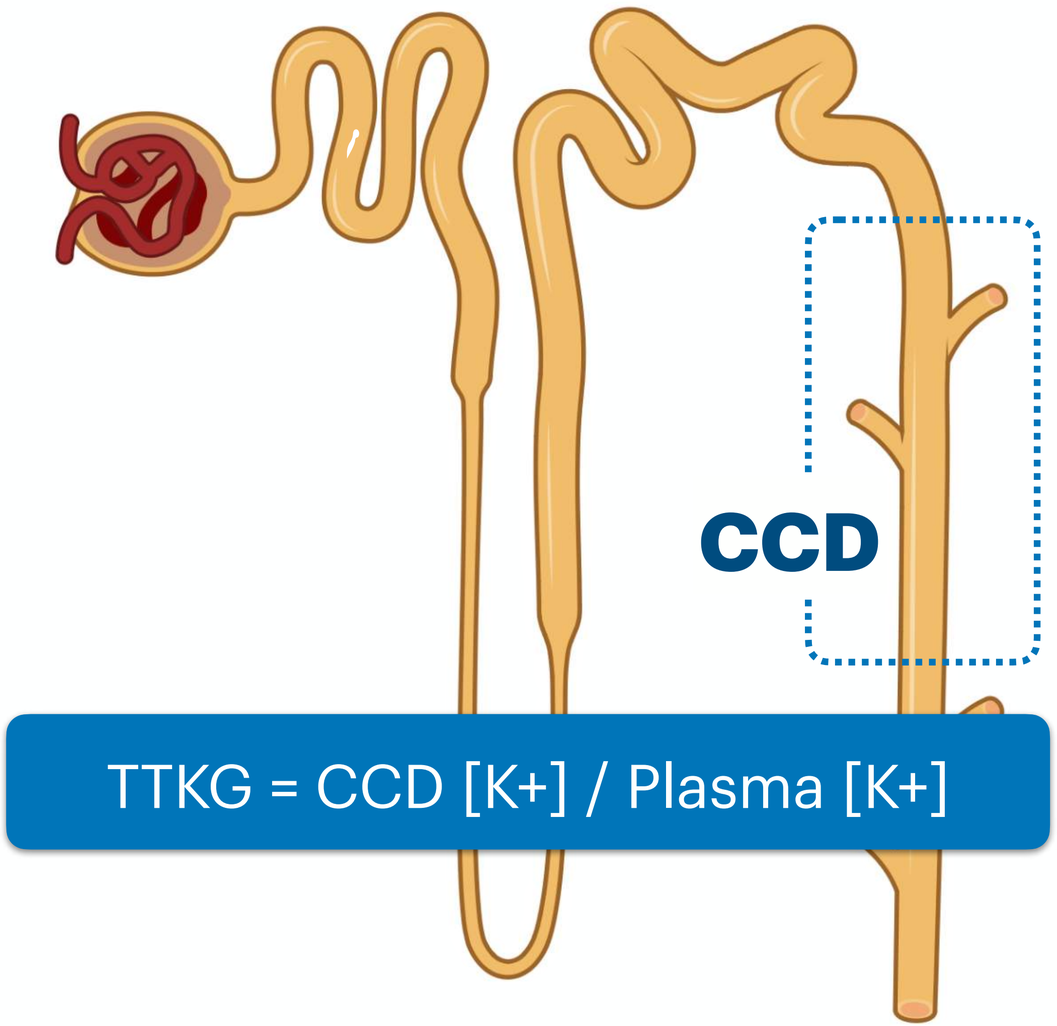
↓PAC, ↓PRA
- Cushing syndrome
- AME
- Liddle

TTKG > 4

Normal BP

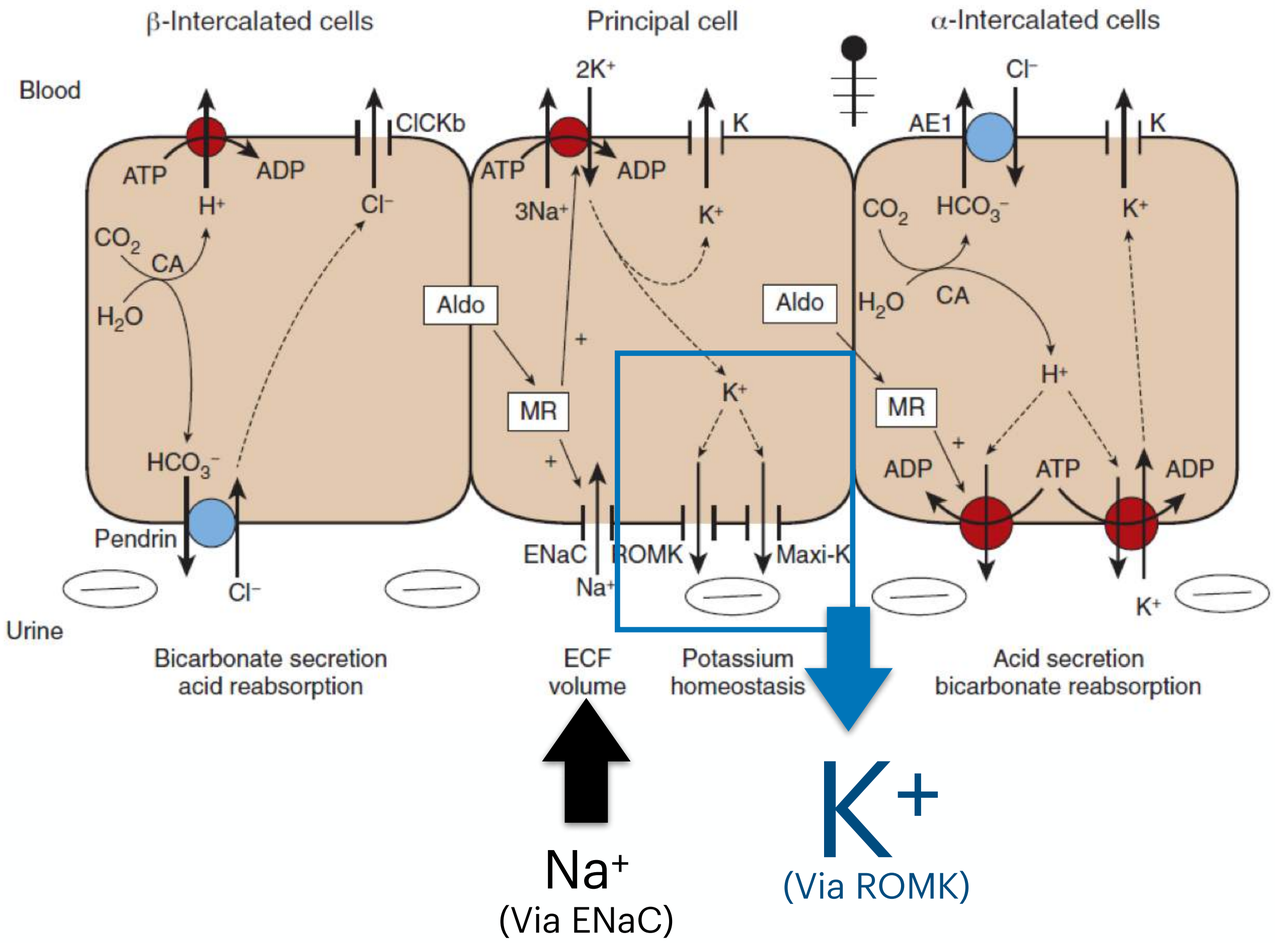
Metabolic **ALKALOSIS**	Metabolic **ACIDOSIS**
UCl > 20 mmol/L	• DKA • RTA • Acetazolamide
UCa/Ucr > 0.2 • Loop diuretic • Bartter's syndrome	mmol/mmolCr
UCa/Ucr < 0.15 • Thiazide • Gitelman syndrome	
UCl < 20 mmol/L • Vomiting • Chloride diarrhea	

TTKG (Transtubular potassium gradient)



TTKG = CCD [K+] / Plasma [K+]

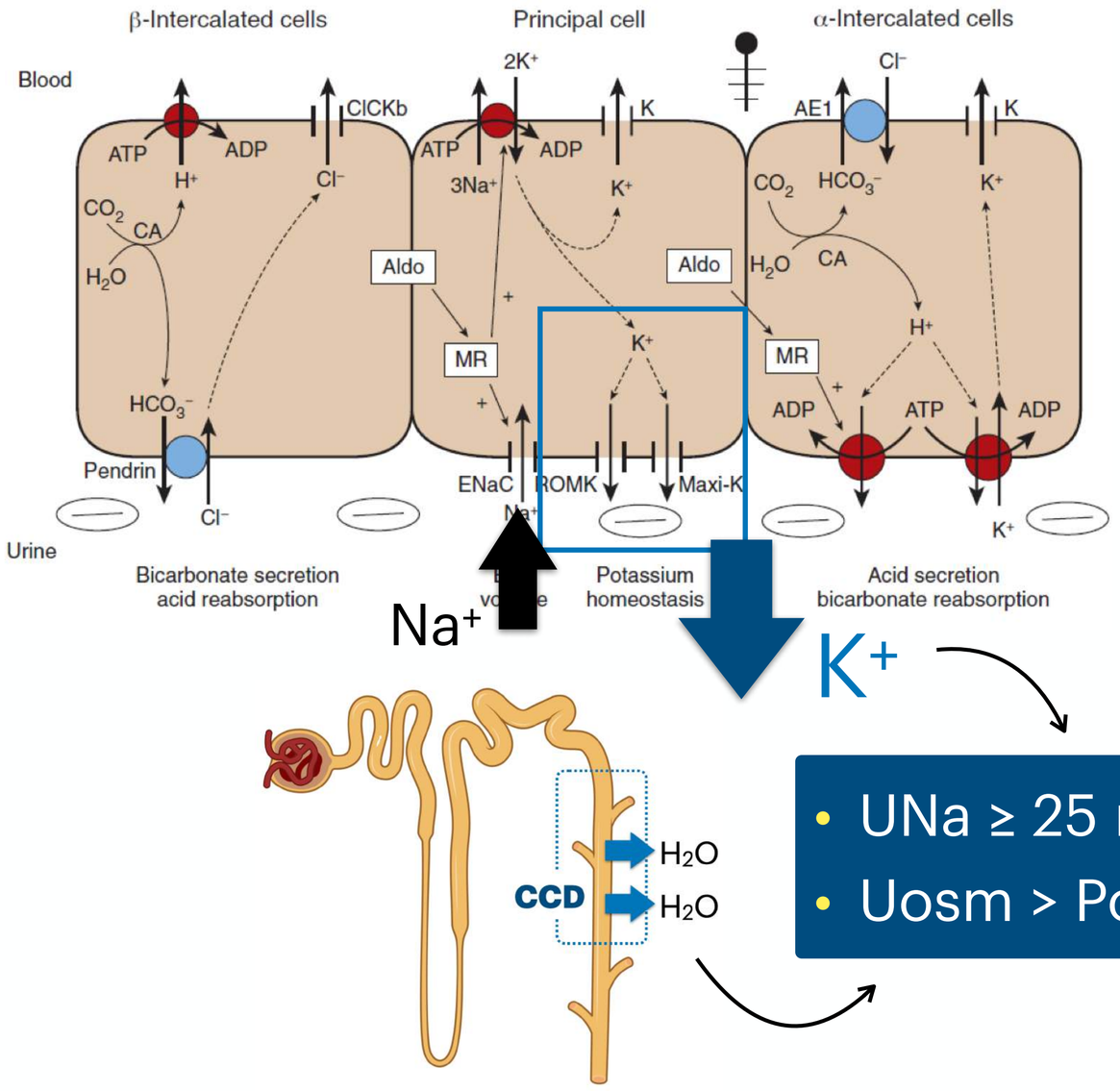
Tubular K^+ secretion



Na^+
(Via ENaC)

K^+
(Via ROMK)

TTKG (Transtubular potassium gradient)



TTKG = CCD [K+] / Plasma [K+]

$$CCD_{osm} = U_{osm}$$

$$CCD_K = \frac{CCD_{osm} \times U_K}{U_{osm}}$$

$$\frac{CCD_K}{P_K} = \frac{CCD_{osm} \times U_K}{U_{osm} \times P_K}$$

- UNa ≥ 25 mmol/L
- Uosm > Posm

$$\textbf{TTKG} = \frac{P_{osm} \times U_K}{U_{osm} \times P_K}$$

HYPOkalemia (K < 3.5 mmol/L)

TTKG < 2

↑Tubular flow → Osmotic diuresis

Extrarenal K+ loss	Renal K+ loss

TTKG > 4

Abnormal tubular K+ secretion

HT + Metabolic **ALKALOSIS**	Normal BP

↑PAC, ↓PRA

↑PAC, ↑PRA

↓PAC, ↓PRA

Renal K+ loss

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- 24h UK > 20 mmol/day
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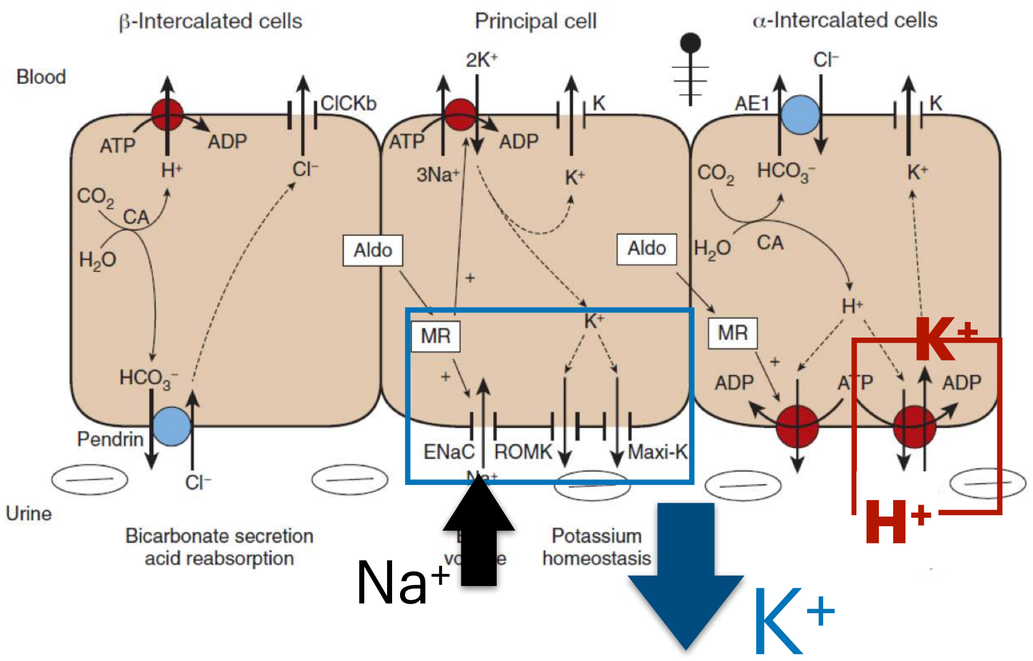

HYPOkalemia ($K < 3.5$ mmol/L)

Extrarenal K^+ loss

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Renal K^+ loss

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Renal K^+ loss

GI secretion	Volume (L/day)	Na^+ (mEq/day)	K^+ (mEq/day)	Cl^- (mEq/day)	HCO_3^- (mEq/day)
Normal stool	< 0.15	20-30	55-75	15-25	0
Vomitus/ NG drainage	0-3	20-100	10-15	120-160	0
Inflammatory diarrhea	**1-3**	50-100	15-20	50-100	**10**
Secretory diarrhea	**1-20**	40-140	15-40	25-105	**20-75**
Ileostomy	**1-1.5**	115-140	5-15	95-125	**30**

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A 30-year-old woman with underlying HIV disease is brought to ER for fatigue and poor appetite. Her current medications include TDF/3TC/EFV, Bactrim and folic acid. She is afebrile, her blood pressure is **110/70** mmHg, pulse rate of 95 beats/min. The physical examination appears normal.

LAB:

HypoK

Metabolic acidosis

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Renal K loss

What is the **MOST** likely cause of her symptoms ?

A. Sjogren syndrome
B. TDF
C. Bactrim
D. Chronic diarrhea

Metabolic ACIDOSIS ($pH < 7.35, HCO_3 < 22$ mmol/L)

Arterial **Vs** Central venous blood gas

	ABG		Central VBG
pH	7.35-7.45	-0.03	7.32-7.42
PaO2	85-100		35-45
PaCO2	35-45	+3	38-48
HCO3	23.58 (SD 8.86)		24.32 (SD =9.8)
SaO2	97-100		70-75

Metabolic ACIDOSIS (pH < 7.35, HCO_3 < 22 mmol/L)

Acid-base abnormalities & compensatory response

Disorder	pH	1º Disturbance	Compensatory response
Acute respiratory acidosis	↓	↑pCO_2	↑pCO_2 10 mmHg → ↑$[HCO_3^-]$ **1** mEq/L
Acute respiratory alkalosis	↑	↓pCO_2	↓pCO_2 10 mmHg → ↓$[HCO_3^-]$ **2** mEq/L
Chronic respiratory acidosis	↓	↑pCO_2	↑pCO_2 10 mmHg → ↑$[HCO_3^-]$ **3.5** mEq/L
Chronic respiratory alkalosis	↑	↓pCO_2	↓pCO_2 10 mmHg → ↓$[HCO_3^-]$ **5** mEq/L
Metabolic **acidosis**	↓	↓HCO_3^-	Expected pCO_2 = **1.5 x $[HCO_3^-]$ + 8 ± 2**
Metabolic **alkalosis**	↑	↑HCO_3^-	Expected pCO_2 = **0.7 x [HCO3-] + 20 ± 2**

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- U_{Na} 50 mmol/L, U_K 50 mmol/L, U_{Cl} 60 mmol/L, U_{Glu} 54 mg/dL, U_{urea} 28 mg/dL
- U_{osm} 300 mOsm/kg

Expected pCO2
= 1.5 [HCO3] + 8 ± 2
= 30.5 ± 2

What is the **MOST** likely cause of her symptoms ?

A. Sjogren syndrome
B. TDF
C. Bactrim
D. Chronic diarrhea

Metabolic ACIDOSIS (pH < 7.35)

Normal **Vs** Wide anion gap metabolic acidosis

Anion gap = $Na - Cl - HCO_3$

Normal ~ 10 ± 2

$$\frac{\Delta AG}{\Delta HCO_3} = \frac{AG - 10}{24 - HCO_3}$$

Corrected AG = (4-Albumin) x 2.5 + AG

< 1: Wide + Normal AG metabolic acidosis

1-2: Pure wide AG metabolic acidosis

> 2: Wide AG metabolic acidosis + metabolic alkalosis

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- U_{osm} 300 mOsm/kg

Anion gap
= Na-Cl-HCO_3
= 6

Normal AG metabolic acidosis

What is the **MOST** likely cause of her symptoms ?

A. Sjogren syndrome
B. TDF
C. Bactrim
D. Chronic diarrhea

Normal anion gap metabolic acidosis

Acid gain

Chloride-rich fluids

- NH_4Cl or HCl

Dilutional acidosis

- NSS > 3-4 L (resuscitation)

HCO_3 loss

Extrarenal loss **(Lower GI)**

- Diarrhea
- Uretero-enteric fistula

Renal loss

- **Proximal RTA** (Type2 RTA)
  - ✓ Variable Urine pH & UAG
  - ✓ Other proximal tubular dysfunction
  - ✓ $FEHCO_3$ > 15 (after HCO_3 loading test)
- **Posthypocapnea**

Abnormal acid excretion

Renal function decline

- AKI
- CKD

Distal RTA

- Normal renal function
- Positive UAG
- UOG < 100 mOSm/kg.H_2O

Normal anion gap metabolic acidosis

HCO3 loss

Extrarenal loss (Lower GI)

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Renal loss

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Ileostomy	**1-1.5**	115-140	5-15	95-125	**30**

Normal anion gap metabolic acidosis

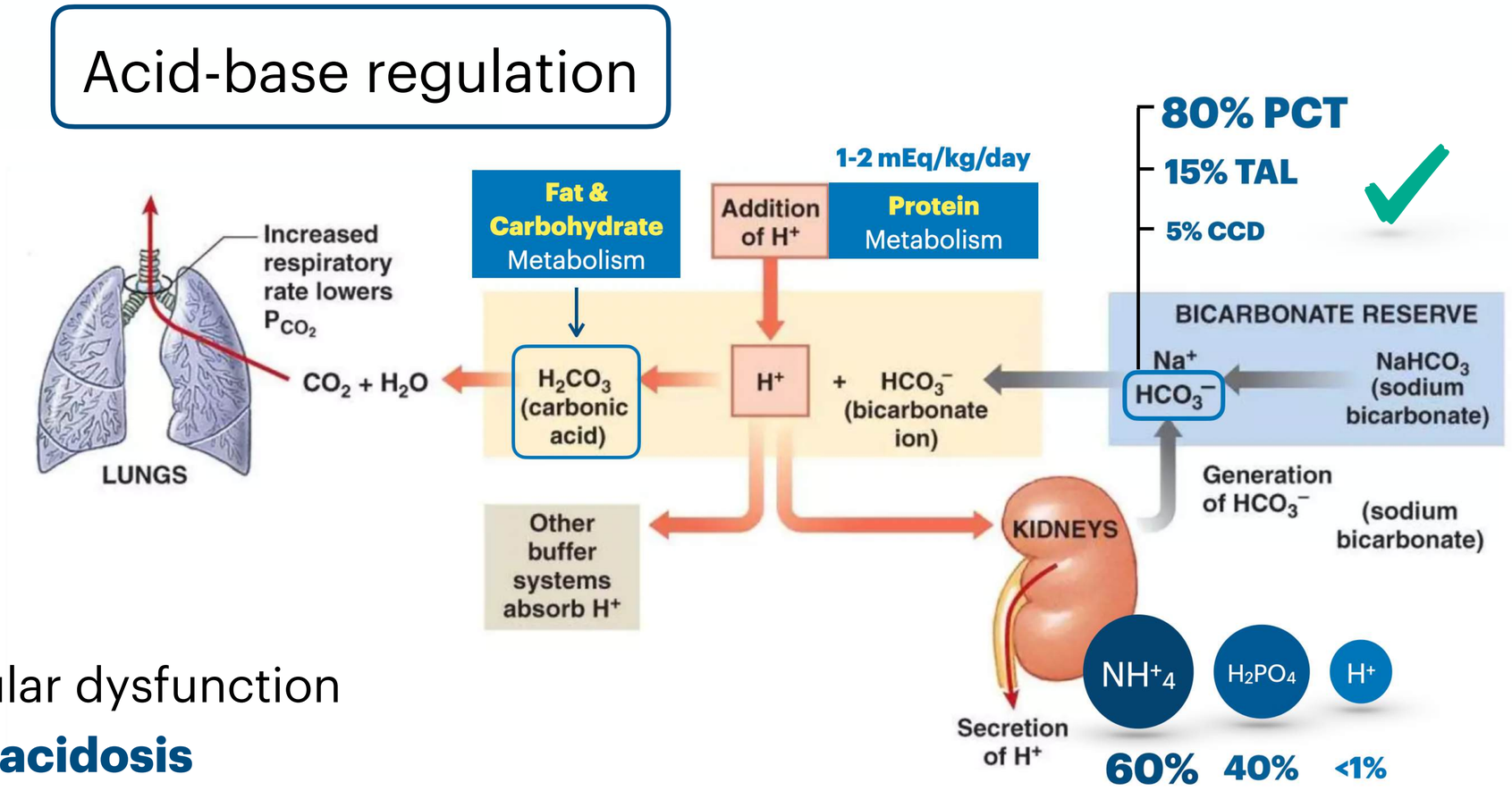
HCO3 loss

Extrarenal loss **(Lower GI)**

- Diarrhea
- Uretero-enteric fistula

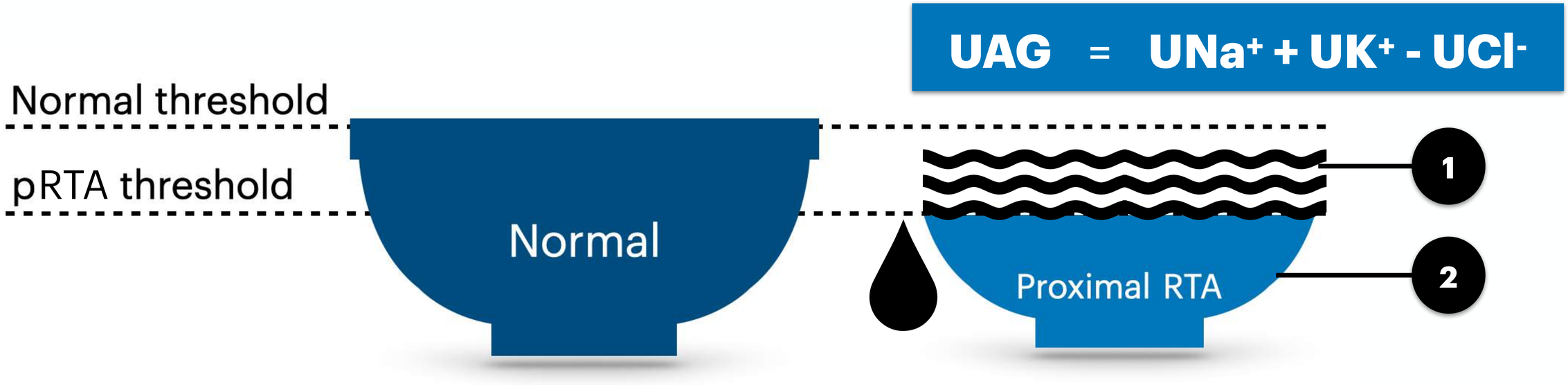
Renal loss

- **Proximal RTA** (RTA type 2)
  - ✓ Variable Urine pH & UAG
  - ✓ Evidence of Proximal tubular dysfunction
- **Posthypocapnic metabolic acidosis**



Normal anion gap metabolic acidosis

Urine pH & UAG in pRTA?



- Serum HCO3 **> threshold** (HCO3 loss): **UpH > 5.5**, **UAG +ve**
- Serum HCO3 **≤ threshold** (No HCO3 loss): **UpH < 5.5**, **UAG -ve**

Normal anion gap metabolic acidosis

HCO3 loss

Extrarenal loss **(Lower GI)**

- Diarrhea
- Uretero-enteric fistula

Renal loss

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  - ✓ Variable Urine pH & UAG
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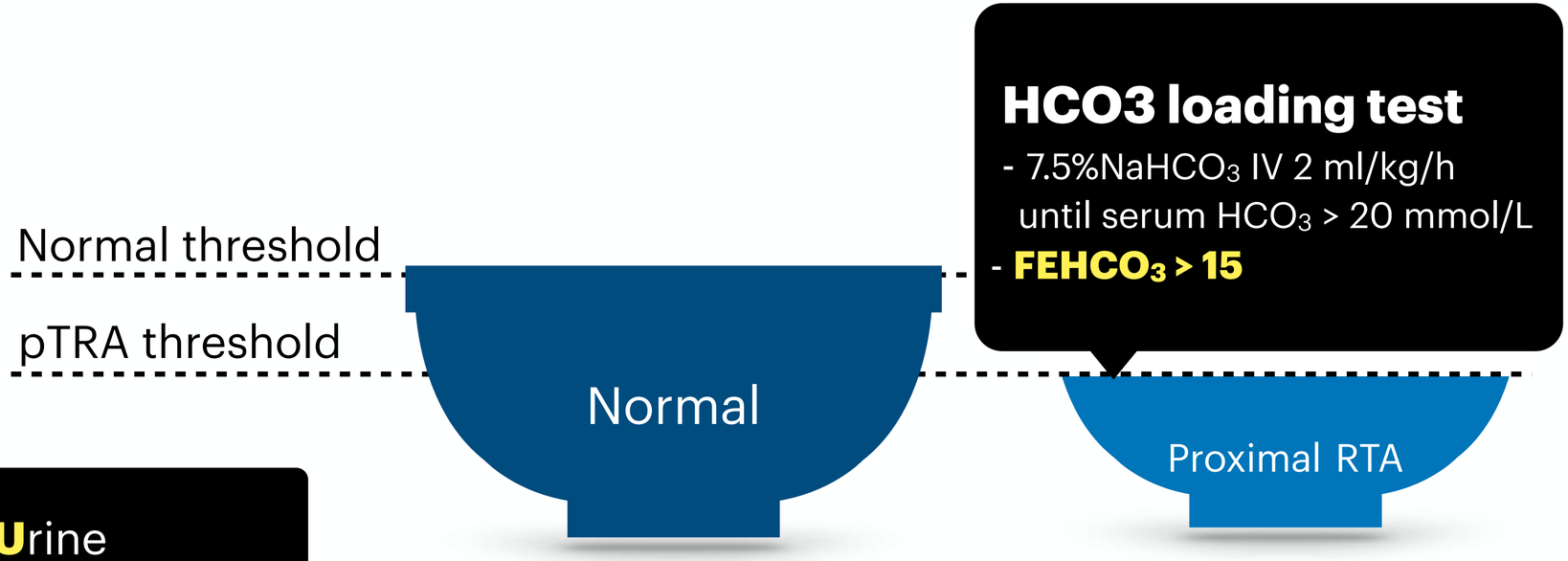
Urine
- **H**CO3
- **U**ric acid
- **G**lucose
- **A**mino acid
- **P**hosphate



Urine anion gap = $UNa^+ + UK^+ - UCl^-$

Serum HCO3	Urine pH	UAG
< threshold	< 5.5	negative
> threshold	> 5.5	Positive

Proximal RTA: Etiology

pRTA associated with **Fanconi's syndrome**	
Primary	Genetic / Sporadic
Genetic	**Wilson**, Tyrosinemia
Dysproteinemia	**Multiple myeloma**
2º Hyperparathyroidism	**Vitamin D** def/resistance
Drugs & toxin	**Ifosfamide**, **TDF**, Lead
Tubulointerstitial disease	Sjogren, **KT**

pRTA (**Isolated** pure bicarbonate wasting)	
Primary	- pTRA + **short stature** (AD) [Mutation of SLC9A3/NHE3] - pRTA + **Ocular abnormalities** (AR) [Missense of SLC4A4] - **Carbonic anhydrase** deficiency
Drugs	- **Acetazolamide**, **Topiramate** - Sulfanilamide, Mafenide acetate

Normal anion gap metabolic acidosis

Acid gain

Chloride-rich fluids

- NH_4Cl or HCl

Dilutional acidosis

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HCO_3 loss

Extrarenal loss **(Lower GI)**

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Abnormal acid excretion

Renal function decline

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Distal RTA

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- Positive UAG
- UOG < 100 mOSm/kg.H_2O

Normal anion gap metabolic acidosis

Urine anion gap (UAG)

Urine cation	=	Urine anion
$UNa^+ + UK^+ + UNH_4^+$ + Unmeasured cation (UC)	=	UCl^- + Unmeasured anion (UA)
$UNa^+ + UK^+ - UCl^-$	=	UA - ($UC+UNH_4^+$)

UAG = $UNa^+ + UK^+ - UCl^-$ = UA-($UC+UNH_4^+$)

UAG **+ve** ➡ **↑UA - ↓(UC + UNH_4^+)**

↓Acid excretion

UAG **-ve** ➡ UA - **↑(UC + UNH_4^+)**

- Keto-anion → Ketoacidosis
- Hippurate → Hippurate
- D-lactic → D-lactic acidosis
- Bicarbonate → Bicarbonaturia
- Antibiotic salt → Carbenicillin

Normal anion gap metabolic acidosis

Urine osmolal gap (UOG)

UOG = Measured Uosm - **Calculated** Uosm

$$Uosm = 2\,(U_{Na} + U_{K}) + \frac{U_{Glucose}}{18} + \frac{U_{Urea}}{2.8}$$

Measured Uosm
- Na+ salt
- K+ salt
- Urea
- Glucose
- **NH4 Salt**

Calculated Uosm
- Na+ salt
- K+ salt
- Urea
- Glucose

UOG

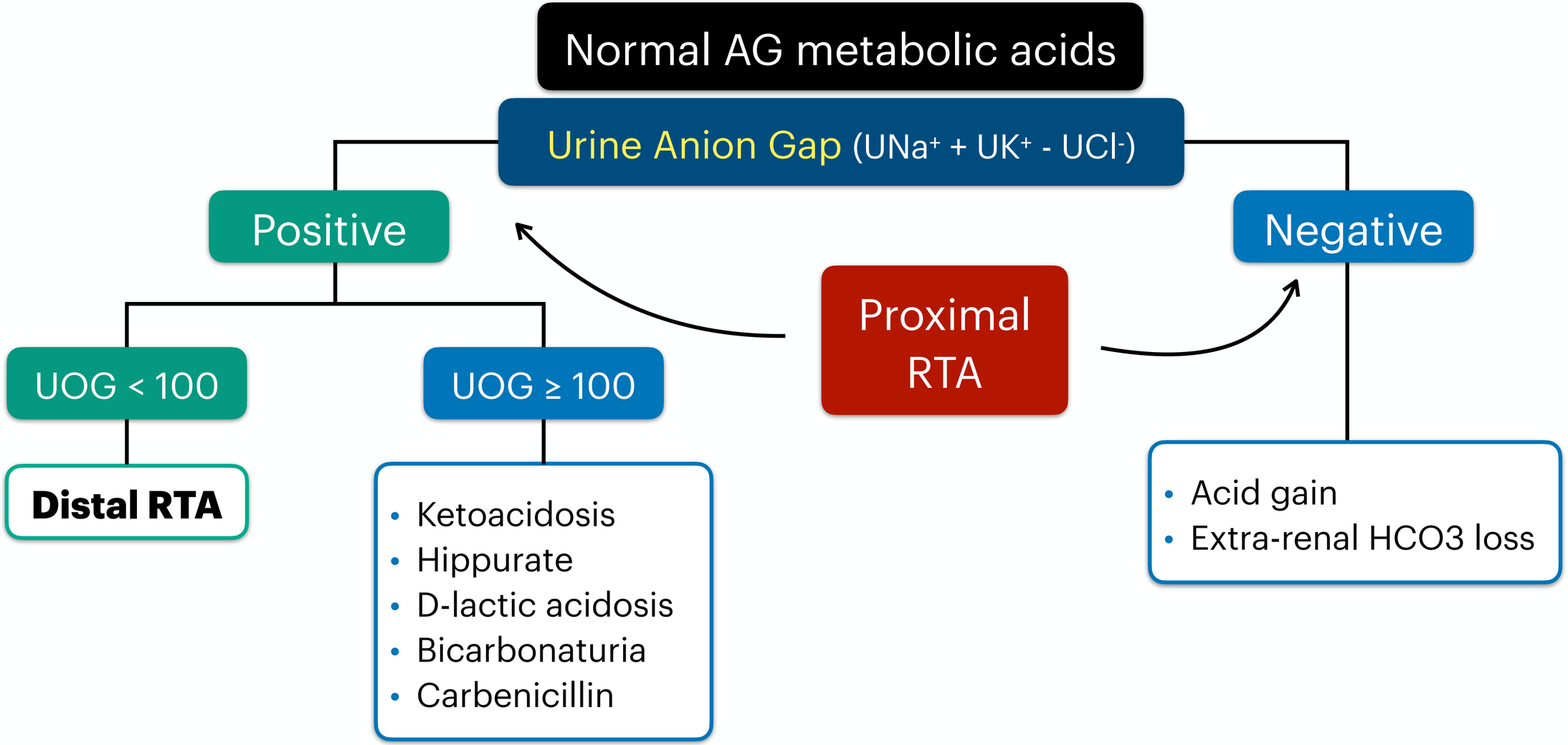
~ 50 meq/day

UOG = 2 x Urine NH_4

NH_4Cl + Other NH_4 Salt

Normal renal acid excretion ➡ **UOG > 100** mOsm/kg.H_2O

Normal anion gap metabolic acidosis



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- U_{osm} 300 mOsm/kg

UAG
= UNa+UK-UCl
= 40 **(+ve)**

Calculated Uosm
= $2(U_{Na}+U_K) + U_{Glu}/18 + U_{Urea}/2.8$
= 213

UOG
= Measured -Calculated Uosm
= 87 **(<100)**

What is the **MOST** likely cause of her symptoms ?

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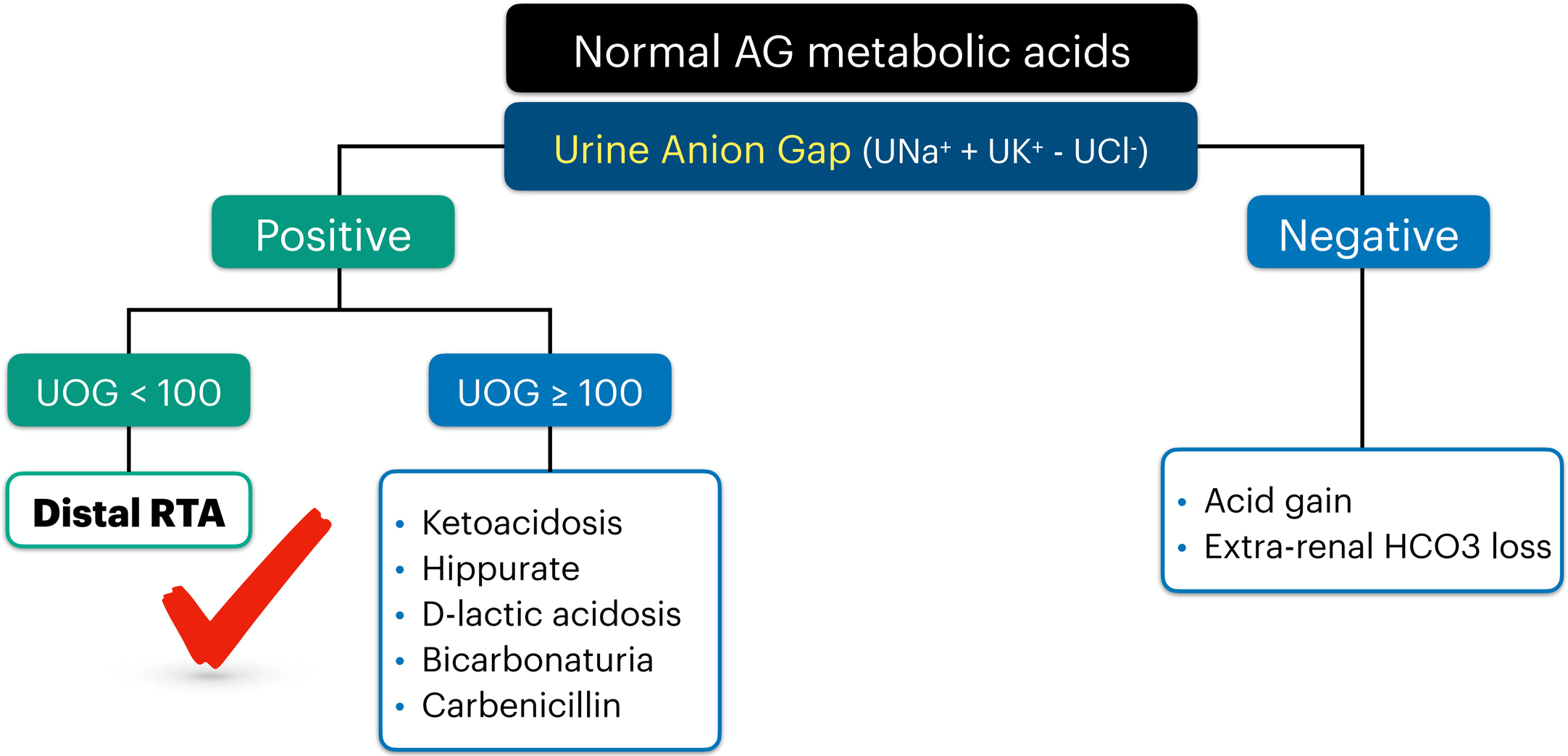
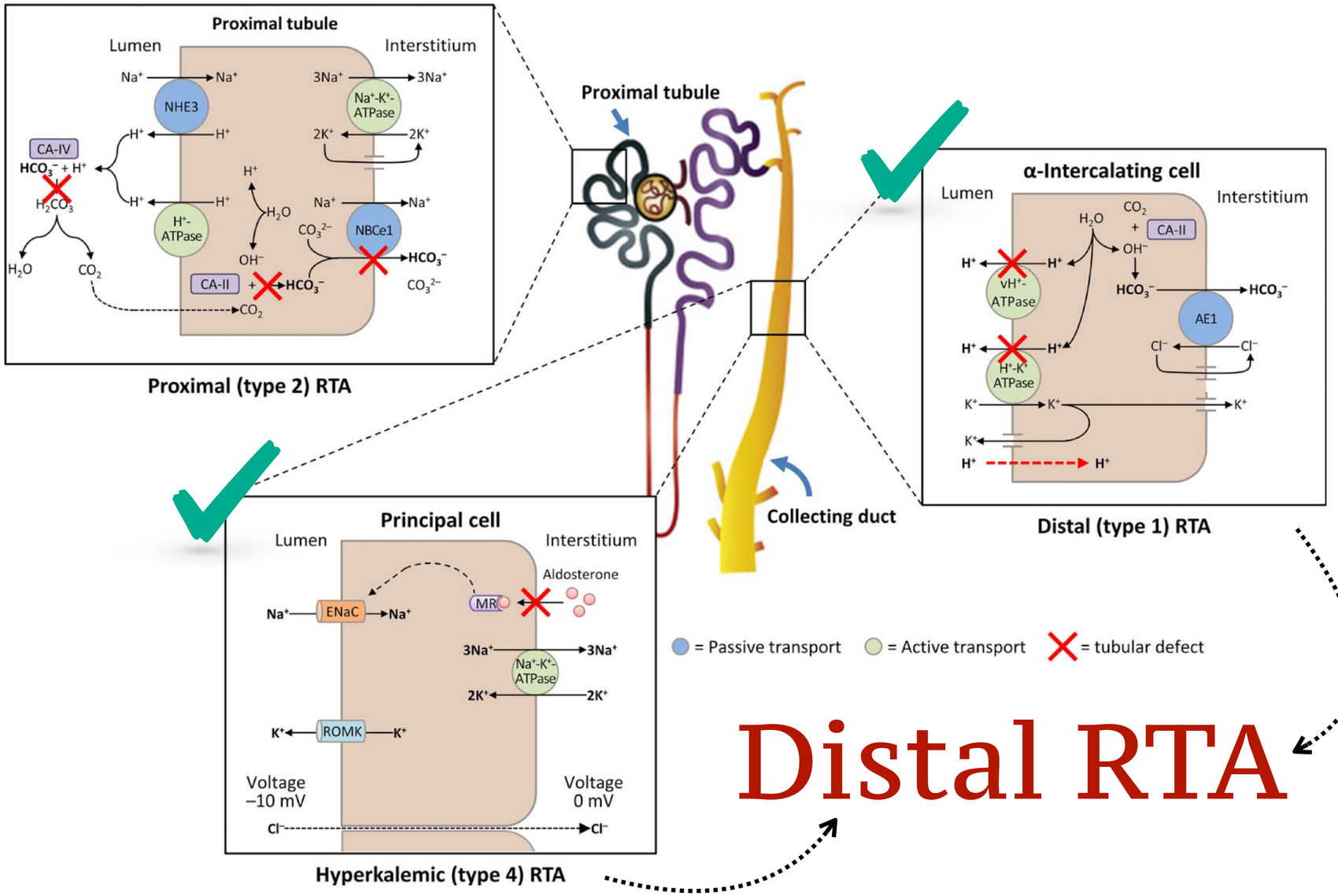
B. TDF
C. Bactrim
D. Chronic diarrhea

Normal anion gap metabolic acidosis



Normal anion gap metabolic acidosis

Renal acid-base regulation



Normal anion gap metabolic acidosis

Distal urinary acidification

Type 1 dRTA

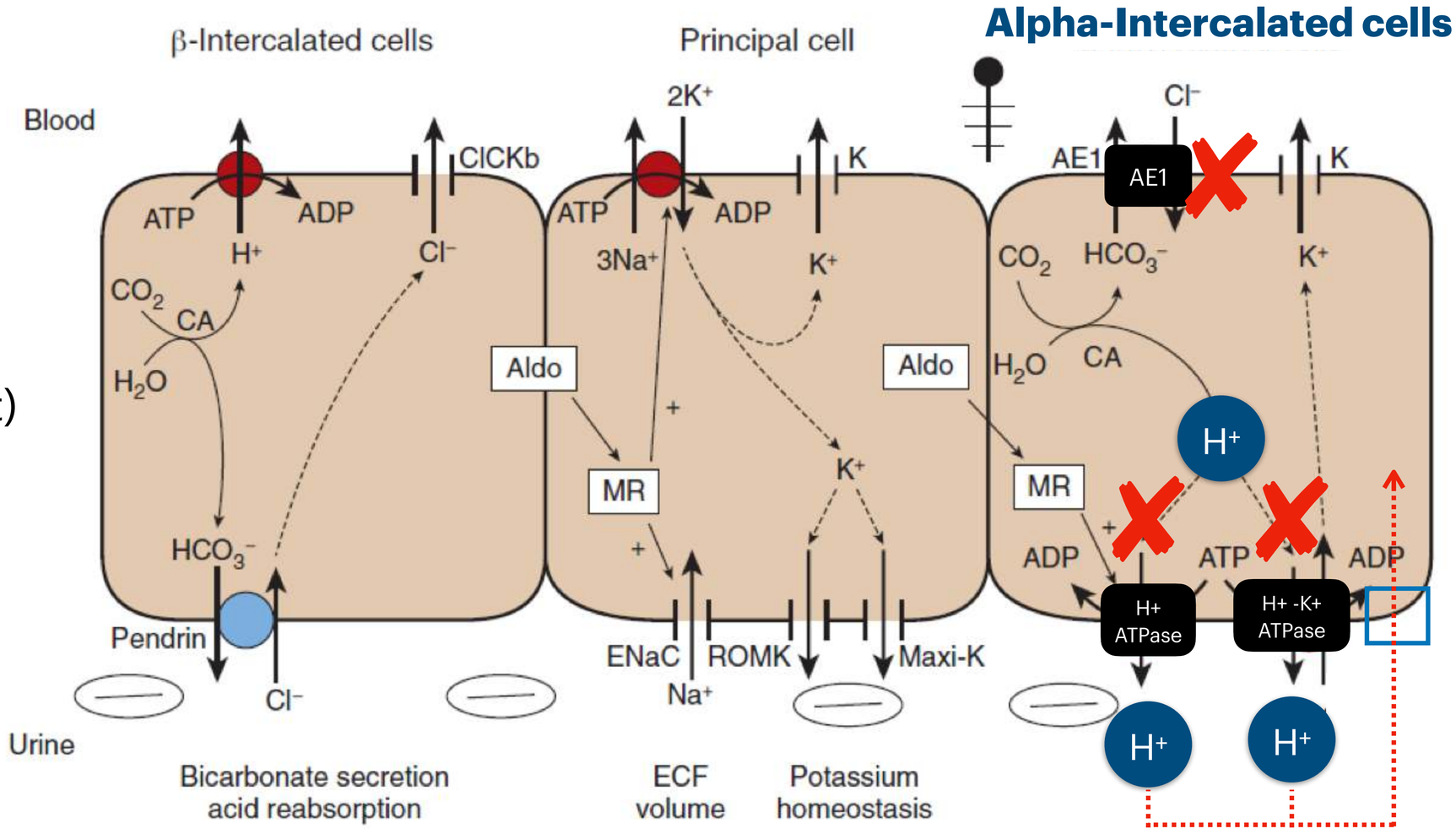
HypoK⁺

Urine pH > 5.5

- **Classic** (Secretory defect)
- **Backleak** (Gradient defect)

Urine pH < 5.5

- **Rate** dependent defect



Normal anion gap metabolic acidosis

Distal urinary acidification

Type 1 dRTA

HypoK⁺

Urine pH > 5.5

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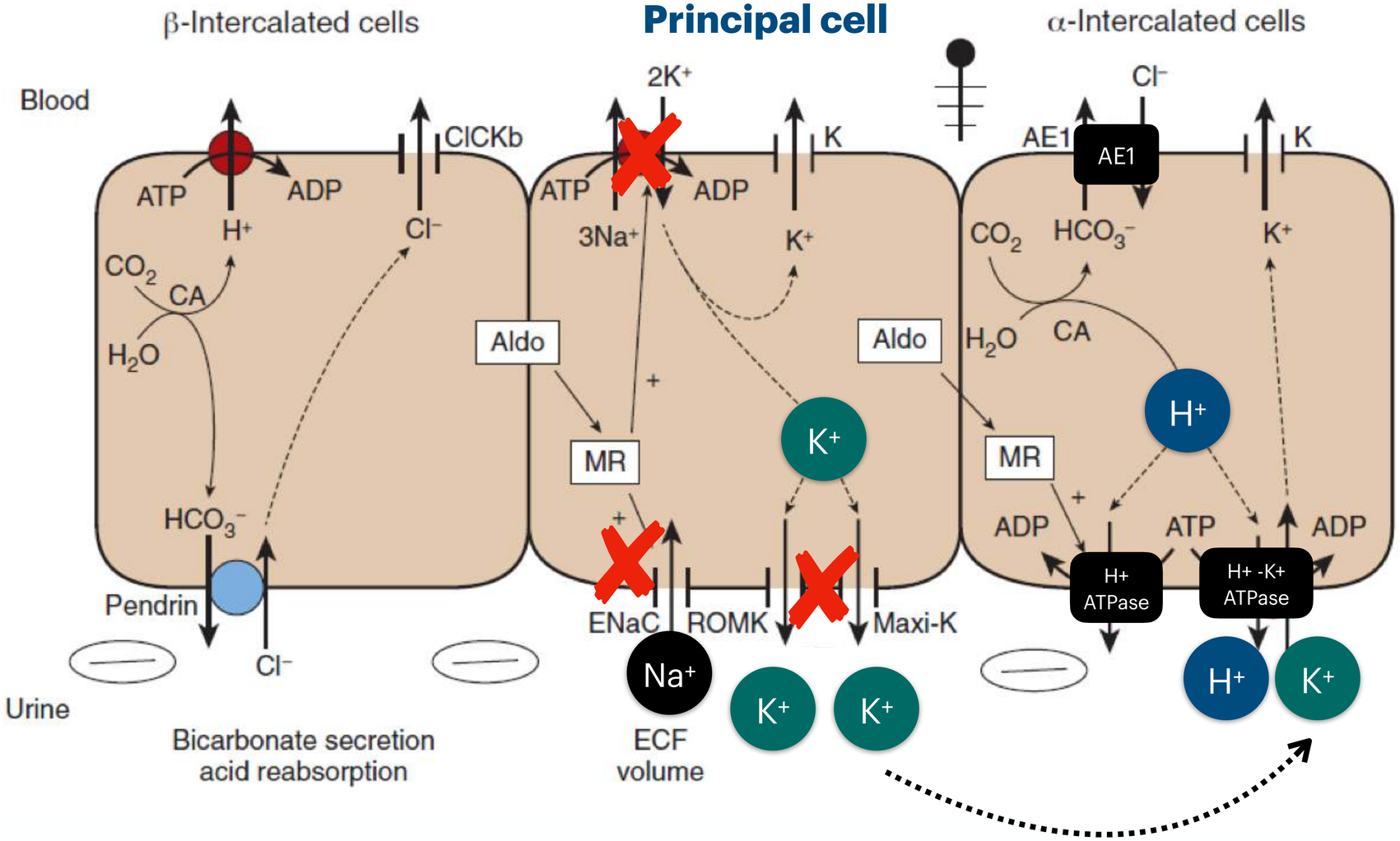
- **Backleak** (Gradient defect)

HyperK⁺

Urine pH > 5.5

- **Voltage** dependent defect



Normal anion gap metabolic acidosis

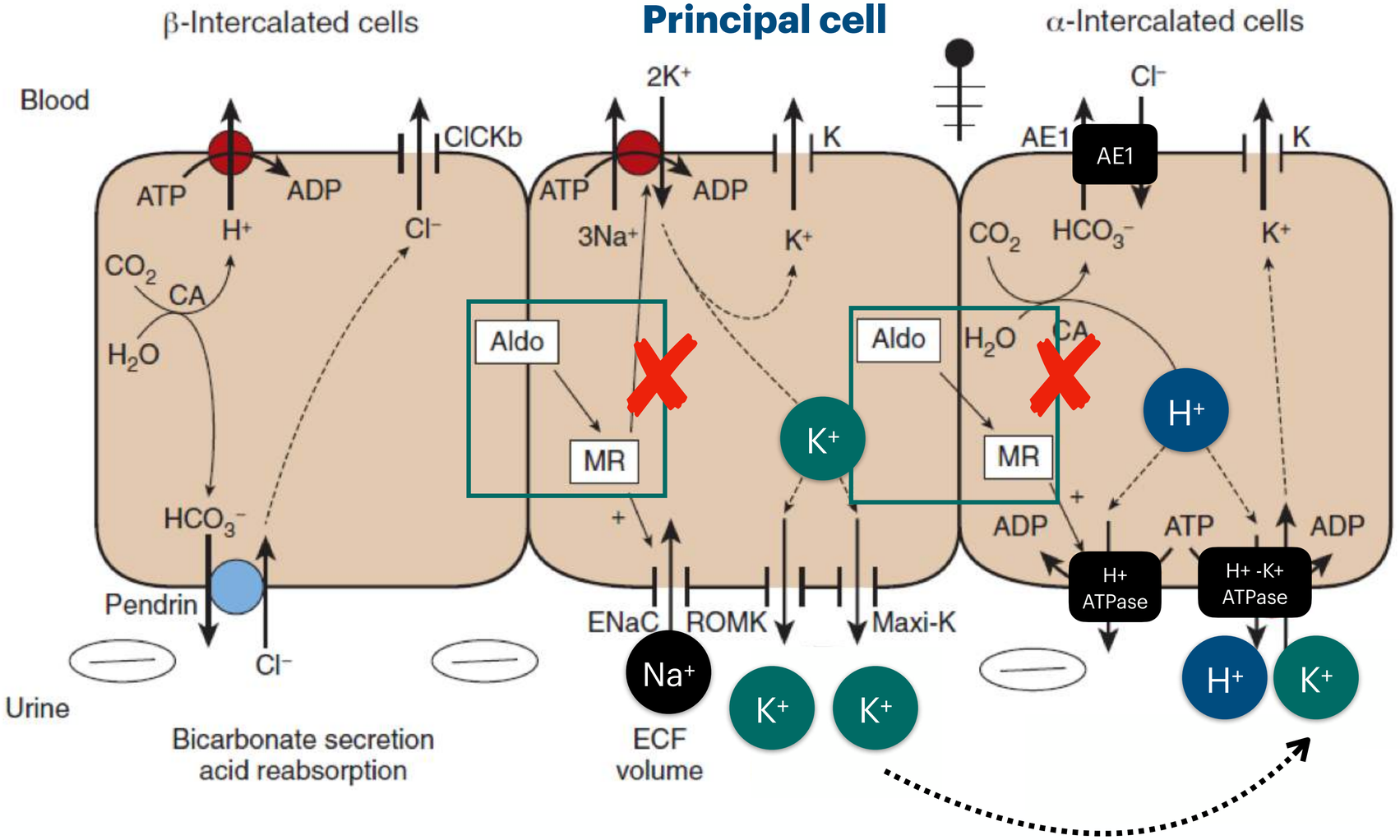
Distal urinary acidification

Type 4 dRTA

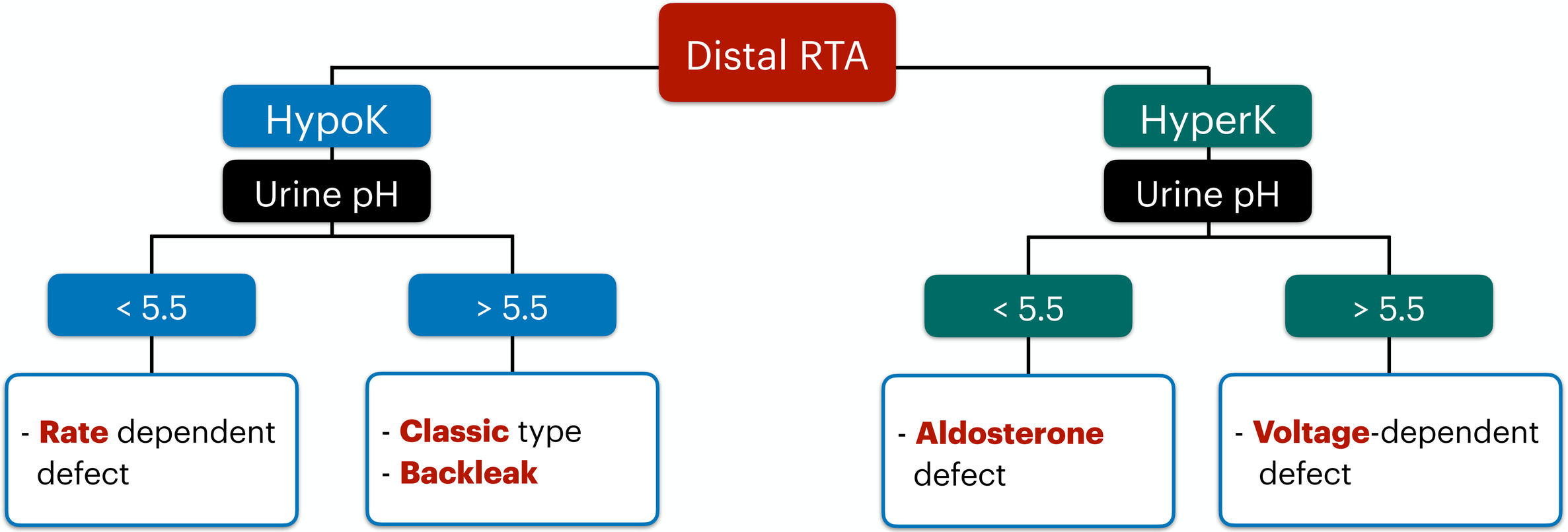
HyperK⁺

Urine pH < 5.5

- **Aldosterone** defect
  - Hypoaldosteronism
  - Aldosterone resistance



Distal RTA: Stepwise approach



Distal RTA: Stepwise approach

Bicarbonate loading test

Method

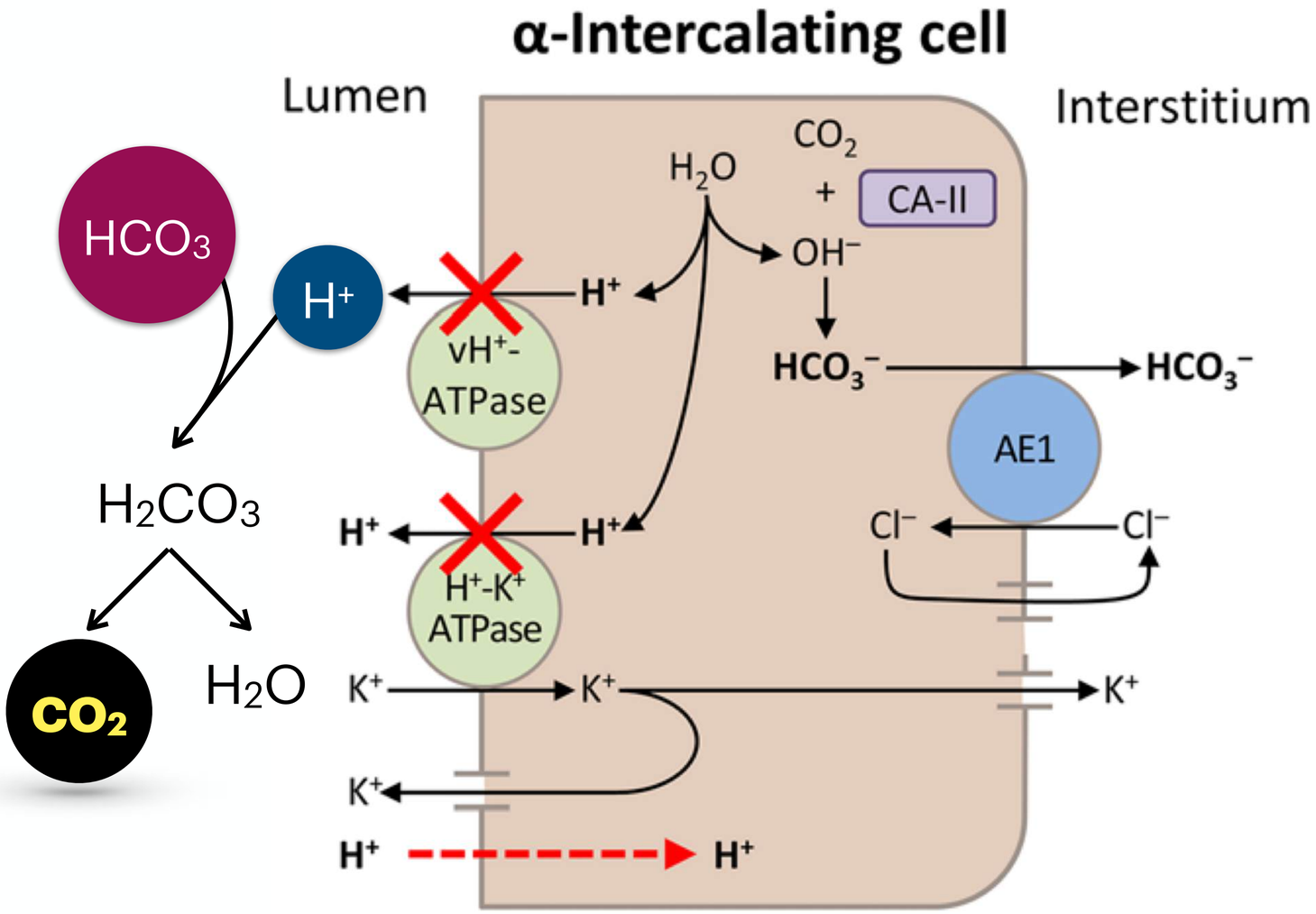
7.5%$NaHCO_3$ IV rate 3 ml/min until Urine pH > 7.8 (~15-30 min)

Classic dRTA (Pump defect)

- Urine pCO_2 **< 50** mmHg
- U-B pCO_2 **< 20** mmHg

Backleak (Gradient defect)

- Urine pCO_2 **> 70** mmHg
- U-B pCO_2 **> 20** mmHg



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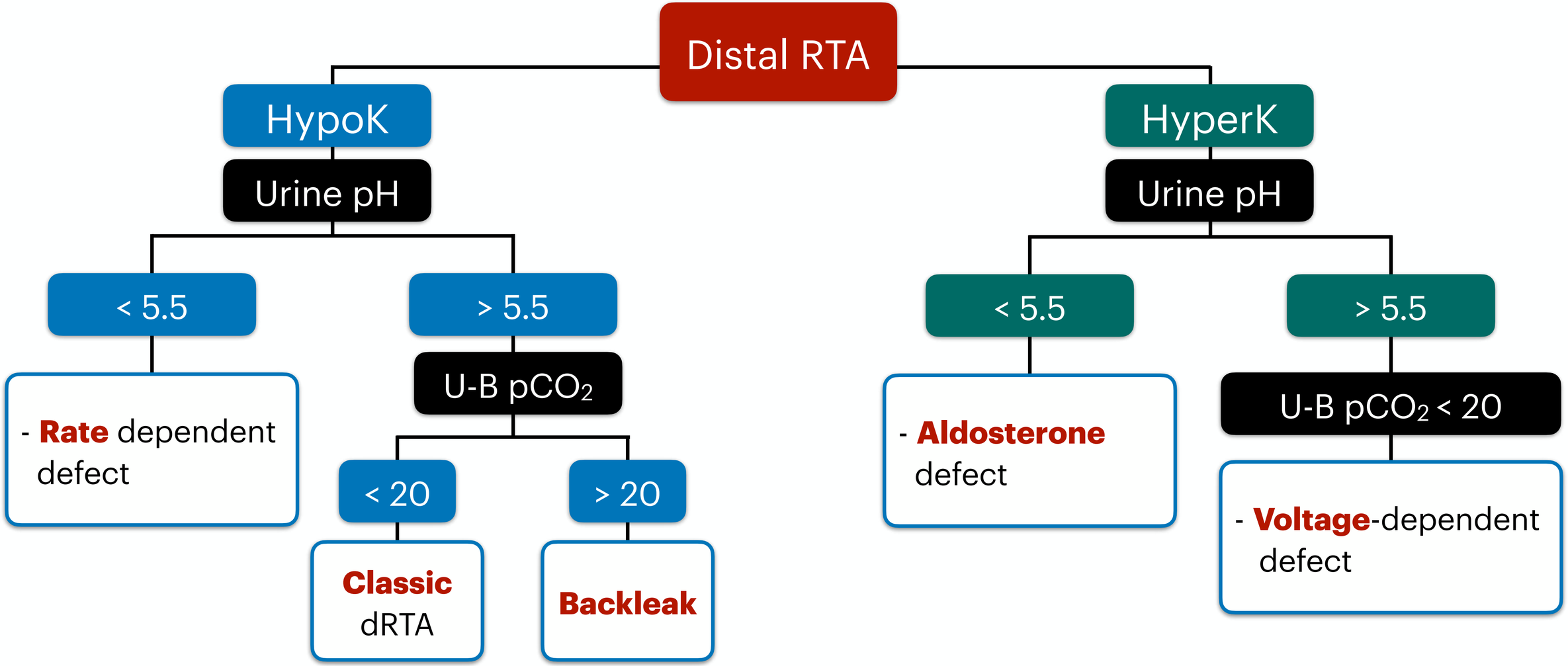
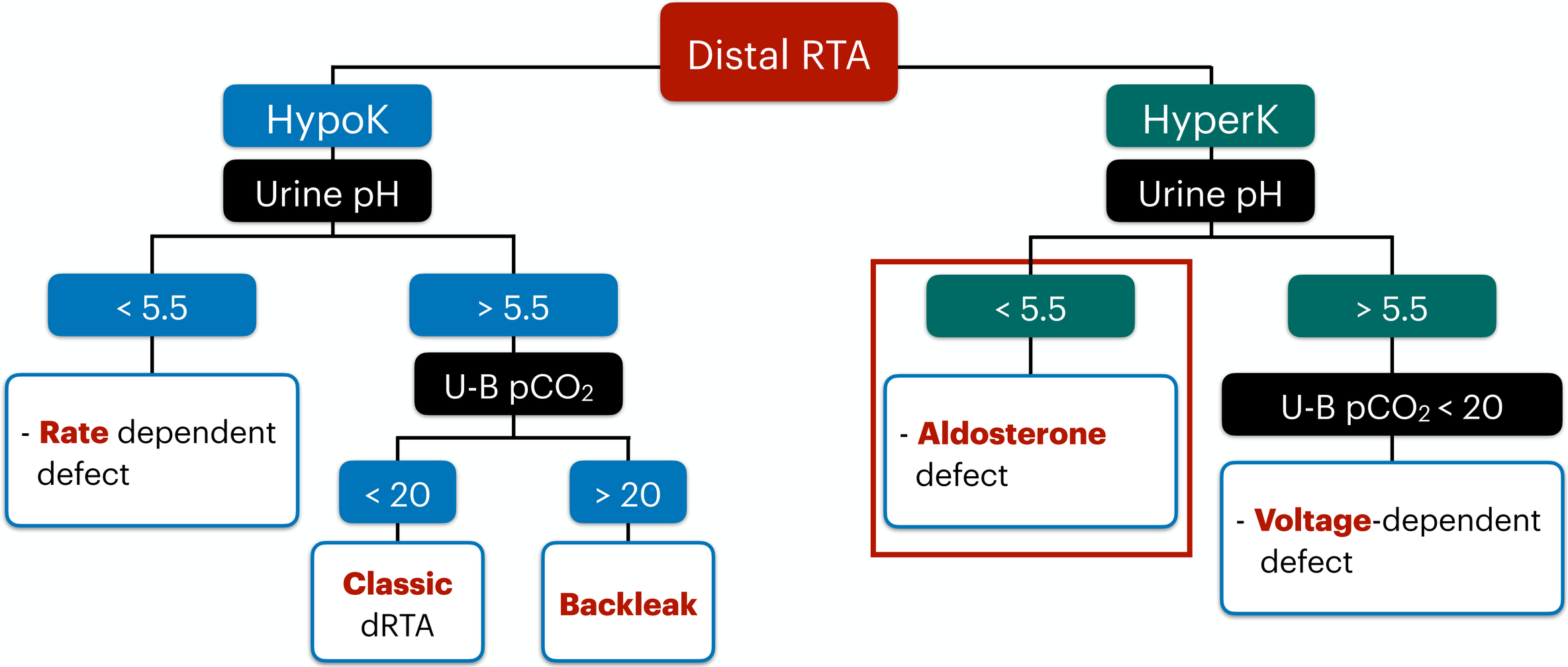


Distal RTA: Stepwise approach

Etiology of hypokalemic distal RTA

Primary	Secondary	
Idiopathic dRTA	Autoimmune	**SLE**, **Sjogren** syndrome, RA, Autoimmune hepatitis, Primary biliary cirrhosis, thyroiditis
Hereditary dRTA with/ without SNHL	Monoclonal gammopathy	**Cryoglobulinemia**, hypergammaglobulinemia
South East Asian Ovalocytosis (SAO) • Band 3 protein • **AR** dRTA • Ovalocytosis	Intrinsic kidney disease	Medullary sponge kidney, post-KT, FSGS
	Drugs & toxins	Ifosfamide, **Amphotericin B**, **Lithium**, Toluene, Foscarnet, Vanadium

Distal RTA: Stepwise approach



Distal RTA: Stepwise approach

Etiology of distal RTA type 4

Renin

A: Acute GN, AIDs **C:** COXi (**NSAIDs**), CNI **T:** TID, KT, UTO

B: β-blockers **D:** DN

Angiotensin I

ACE

Angiotensin II

ACE-i/ ARB

Adrenal gland

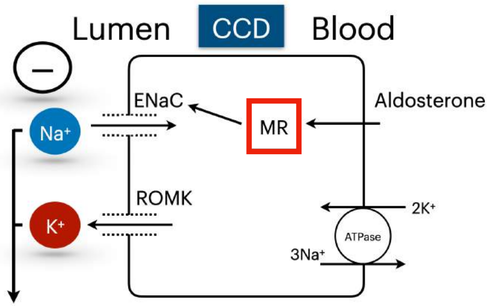
Primary AI: Autoimmune, Infection, 21-hydroxylase deficiency

Drug: **Heparin**, **Ketoconazole**, Etomidate

Aldosterone receptor

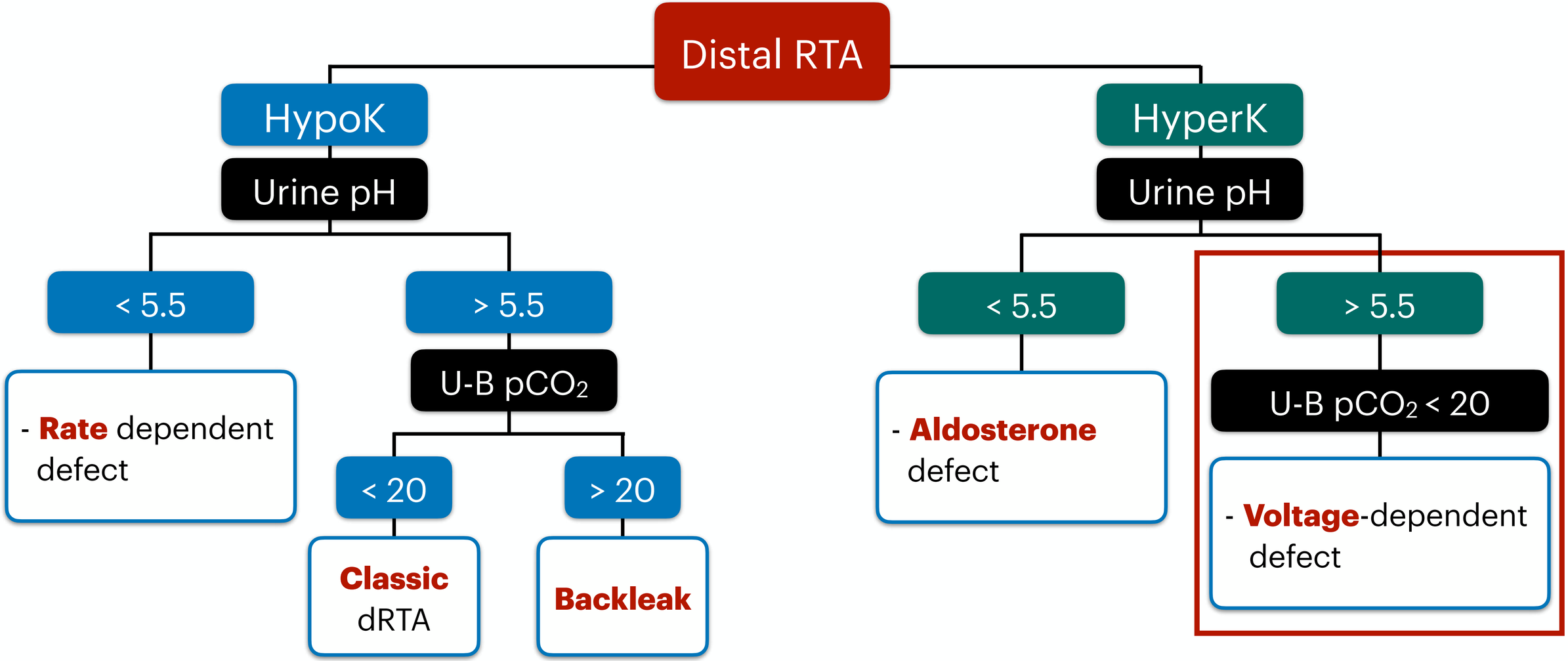
Inherited disease: **PHA1b** [MR defect, (AD)]

MR antagonist: Spironolactone



PHA: Pseudohypoaldosteronism

Distal RTA: Stepwise approach

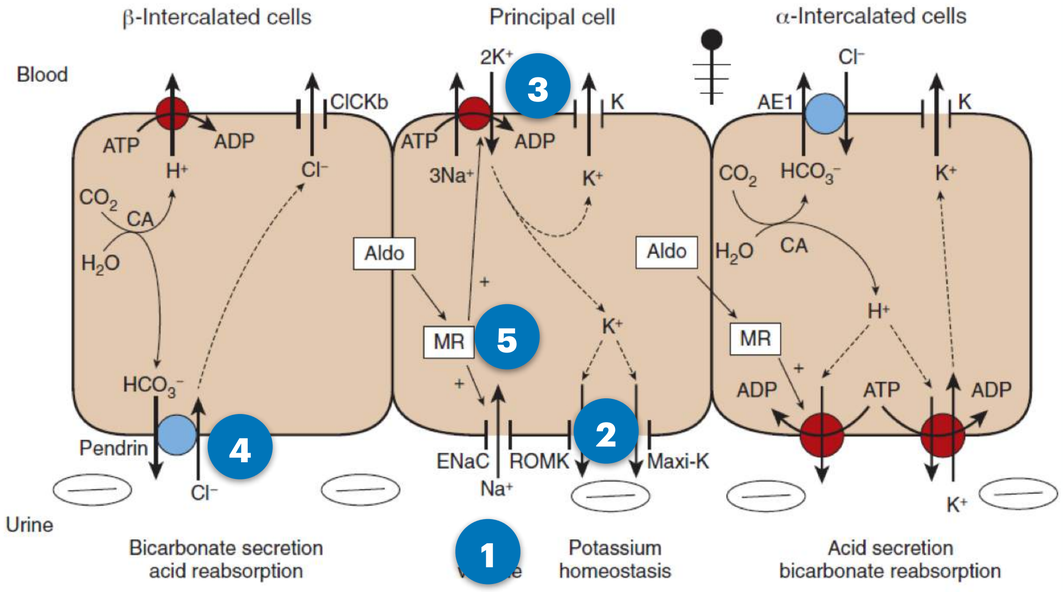


Distal RTA: Stepwise approach

Etiology of voltage-dependent distal RTA

Inherited disease	Tubulointerstitial disease	Drugs
PHA type Ia; AR (**ENac** defect)	Urinary tract obstruction	**ENaC inhibitor** **A:** Amiloride **P:** Pentamidine **T:** Triamterene **T:** Trimethoprim
PHA type II; AD (**NCC** gain function) ***Gordon syndrome***	Kidney transplant	**Calcineurin inhibitor** - Tacrolimus - Cyclosporine

PHA: Pseudohypoaldosteronism



CNI Vs voltage-dependent dRTA

Case 1:

A 30-year-old woman with underlying HIV disease is brought to ER for fatigue and poor appetite. Her current medications include TDF/3TC/EFV, Bactrim and folic acid. She is afebrile, her blood pressure is 110/70 mmHg, pulse rate of 95 beats/min. The physical examination appears normal.

LAB:

Normal AG metabolic acidosis

- Na 136 mmol/L **K 2.0** mmol/L Cl 115 mmol/L **HCO_3 15** mmol/L
- BUN 15 mg/dL Cr 0.52 mg/dL
- ABG: pH 7.25 pCO_2 30 paO_2 98 HCO_3 9
- UA: **pH 7**, glucose neg, Alb neg, wbc 0-1, rbc 0-1
- U_{Na} 50 mmol/L, U_K 50 mmol/L, U_{Cl} 60 mmol/L
- U_{osm} 300 mOsm/kg

What is the **MOST** likely cause of her symptoms ?

A. Sjogren syndrome B. TDF

C. Bactrim D. Chronic diarrhea

Case 2:

An 18-year-old woman presents with proximal muscle weakness for 2 weeks. Her blood pressure is 120/80 mmHg and her pulse rate is 80 beats/min. Physical examination revealed proximal muscle weakness of all extremities. Other findings are unremarkable.

LAB:

- Na 136 mmol/L K 2.8 mmol/L Cl 90 mmol/L HCO3 38 mmol/L
- BUN 15 mg/dL Cr 0.58 mg/dL, eGFR 113.2 ml/min/1.73m^2
- UNa 10 mmol/L, UK 60 mmol/L, UCl 10 mmol/L, UCr 80 mg/dL
- WBC 6500/mm^3 (N80% L10%) Hct 35% Plt 250000/mm^3

What is the **MOST** likely cause of her abnormal condition?

A. Gitelman syndrome

B. Bulimia nervosa

C. Recent diuretic use

D. Liddle syndrome

HYPOkalemia (K < 3.5 mmol/L)

Pseudohyperkalemia: ↑**WBCs** (> 100,000/mm^3)

Renal K$^+$ loss
- Spot UK > 15 mmol/L
- 24h UK > 20 mmol/day
- UK/UCr > 1.5 mEq/mmolCr
- UK/UCr > 13 mEq/gCr

Shift
- Insulin
- ß$_2$-agonist
- Refeeding syndrome
- Periodic paralysis
- Theophylline
- Chloroquine

Loss

Extrarenal loss

ACIDOSIS
- Diarrhea (Upper GI)

VARIABLE
- Profuse sweating

ALKALOSIS
- Vomiting (Lower GI)

Renal loss

HT + Metabolic alkalosis

↑PAC, ↓PRA
- PA, GRA

↑PAC, ↑PRA
- RAS, RST, Malignant HT

↓PAC, ↓PRA
- Cushing, Liddle, AME

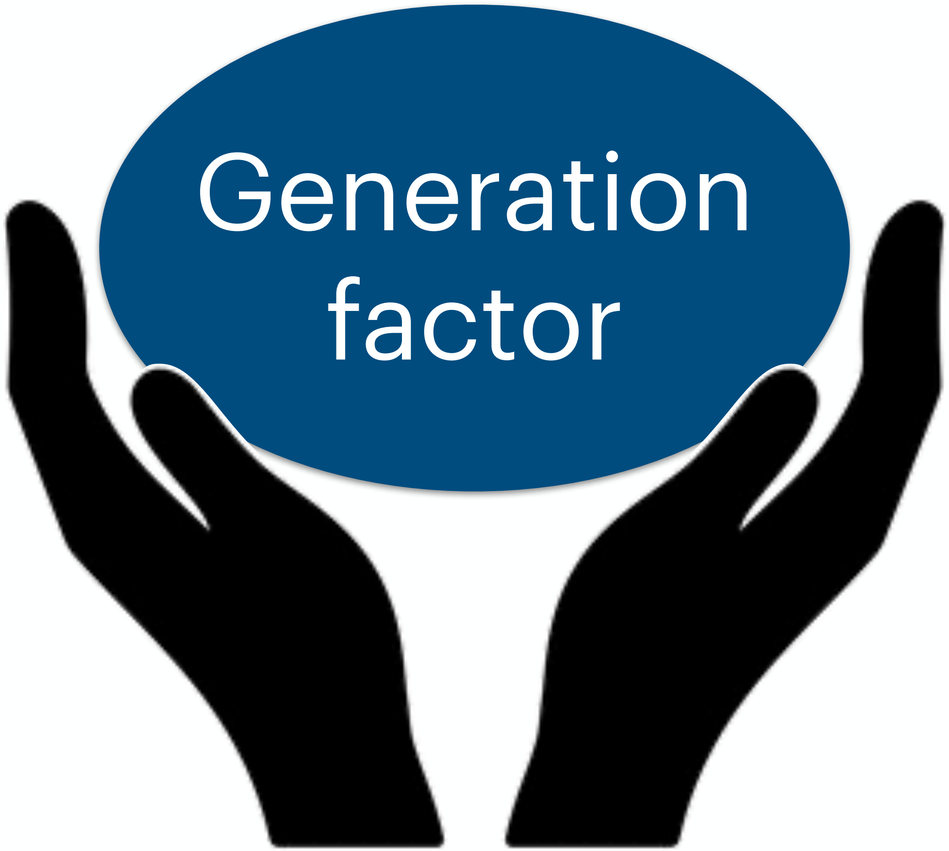
Normal BP

ACIDOSIS
- DKA, RTA, Acetazolamide

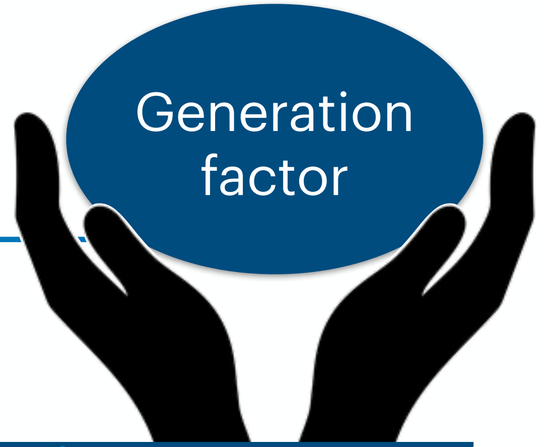
ALKALOSIS
- Cl resistance (U_{Cl} >20)
- Cl responsive (U_{Cl} < 20)

Metabolic Alkalosis (pH > 7.45)

Venous [HCO_3] > 30 mmol/L or Arterial [HCO_3] > 28 mmol/L



Metabolic Alkalosis

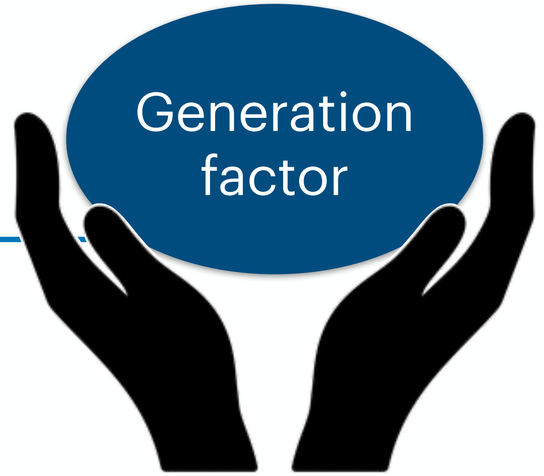


pH > 7.45, Venous [HCO_3] > 30 mmol/L

H+ Loss/ Shift	Gain HCO3		Contraction alkalosis
	Exogenous	Endogenous	
Upper GI loss (Vomiting, NG suction)	Absorbable alkaline (**Sodamint, $AlOH_3$**)	Lactate	**Volume contraction***
	Calcium (Milk) alkali syndrome*	Ketone	
Renal loss	IV fluid (**NaHCO3, RLS**)	Citrate	
H+ shift into cells (hypoK, refeeding syndrome)	**Blood** transfusion (**Citrate**)	Organic anion	
	TPN (**Acetate**, Glutamate)		

Metabolic Alkalosis

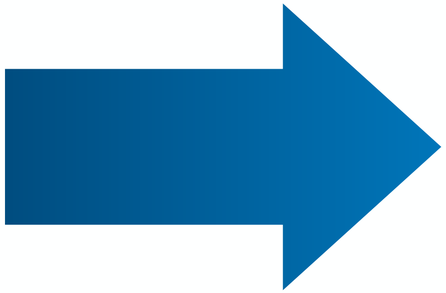
Contraction alkalosis



HCO_3 528 mEq

ECV 22 L

$[HCO_3]$ **24** mEq/L

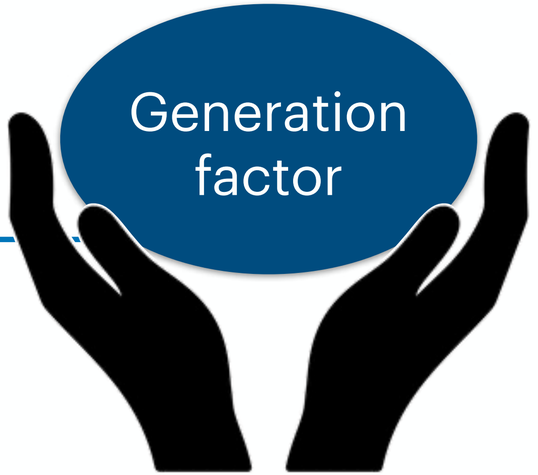


HCO_3 528 mEq

ECV 16 L

$[HCO_3]$ **33** mEq/L

Metabolic Alkalosis



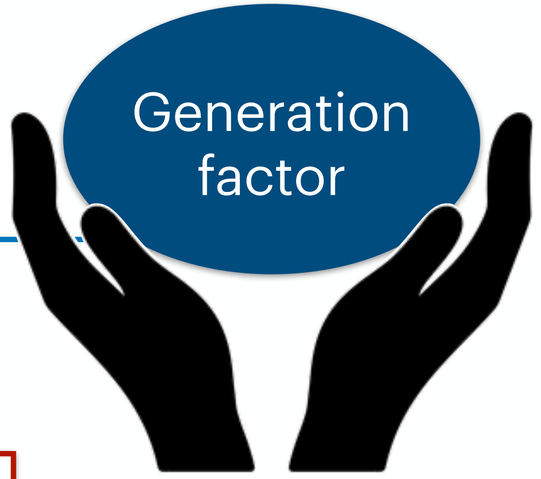
Calcium alkali syndrome

Risk factors:

- High Ca intake (**>4 g** of elemental Ca)
- Concomitant intake with **vitamin D** (↑Ca absorption)
- Pre-existing **CKD**

Triads: Hypercalcemia + Metabolic alkalosis + Renal insufficiency

Metabolic Alkalosis



Calcium alkali syndrome

Calcium load

Alkali load

↑Ca reabsorption

Hypercalcemia

Metabolic alkalosis

↑Acid excretion

↑HCO_3 excretion

- **Renal vasoconstriction**
- **Volume depletion** (polyuria)
  - Nephrogenic DI
  - Natriuresis

↓eGFR

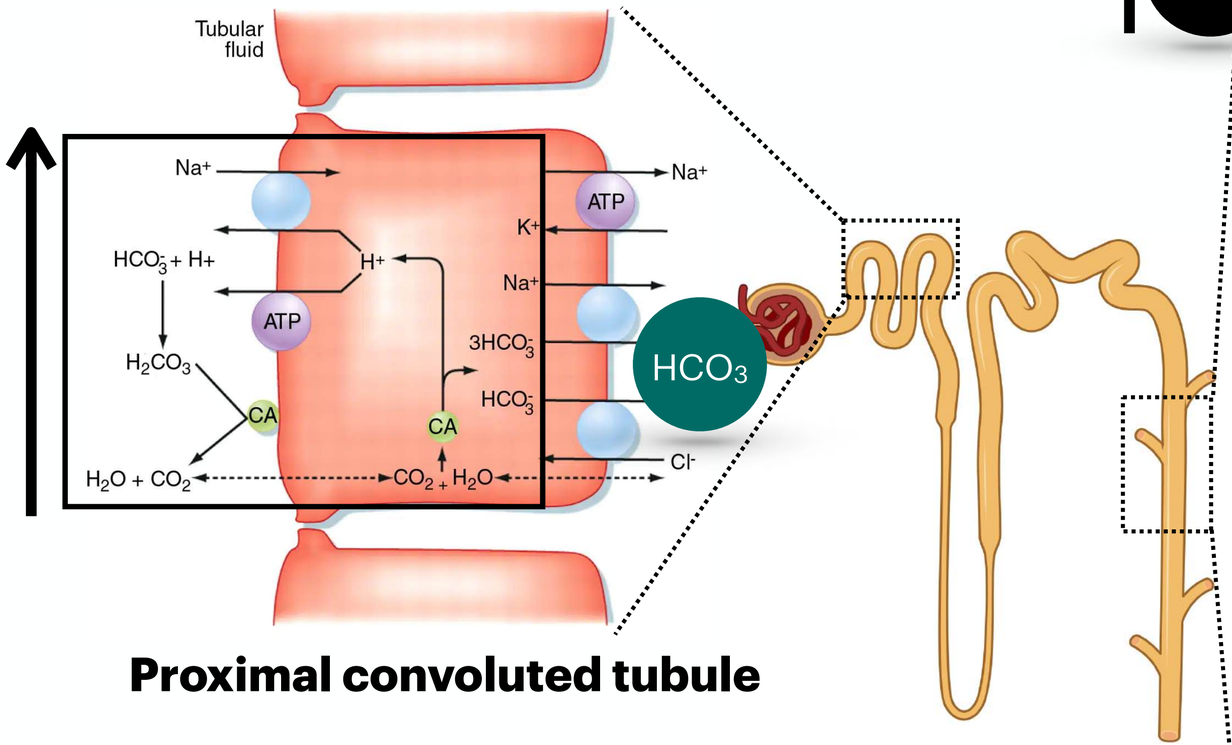
↓Ca & acid excretion

Management:

- Discontinue offending drug
- IV hydration

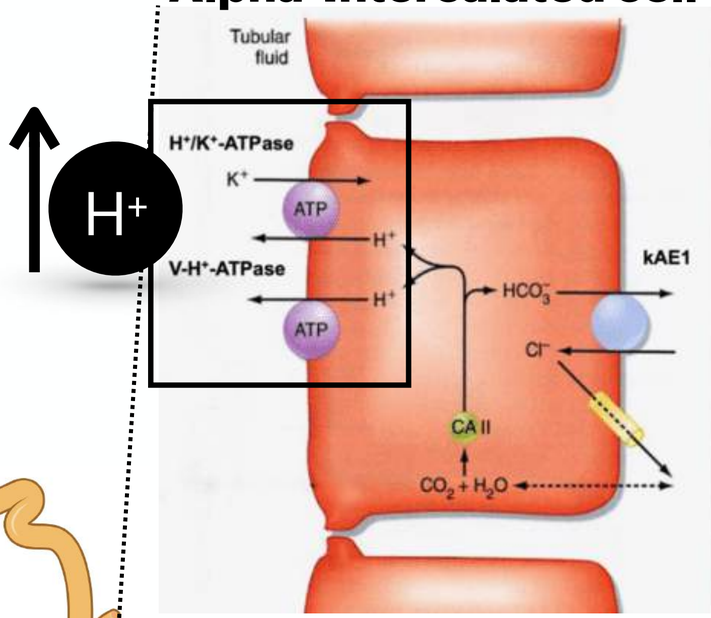
Metabolic Alkalosis

Renal acid-base regulation



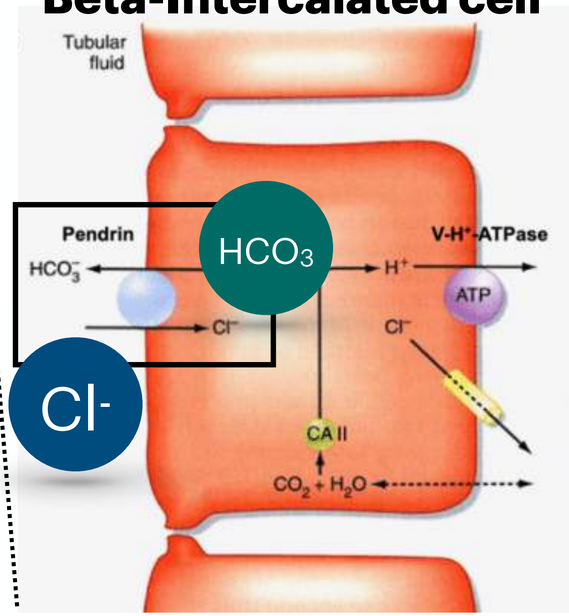
Proximal convoluted tubule

Alpha-Intercalated cell



H+

Beta-Intercalated cell



Cl-

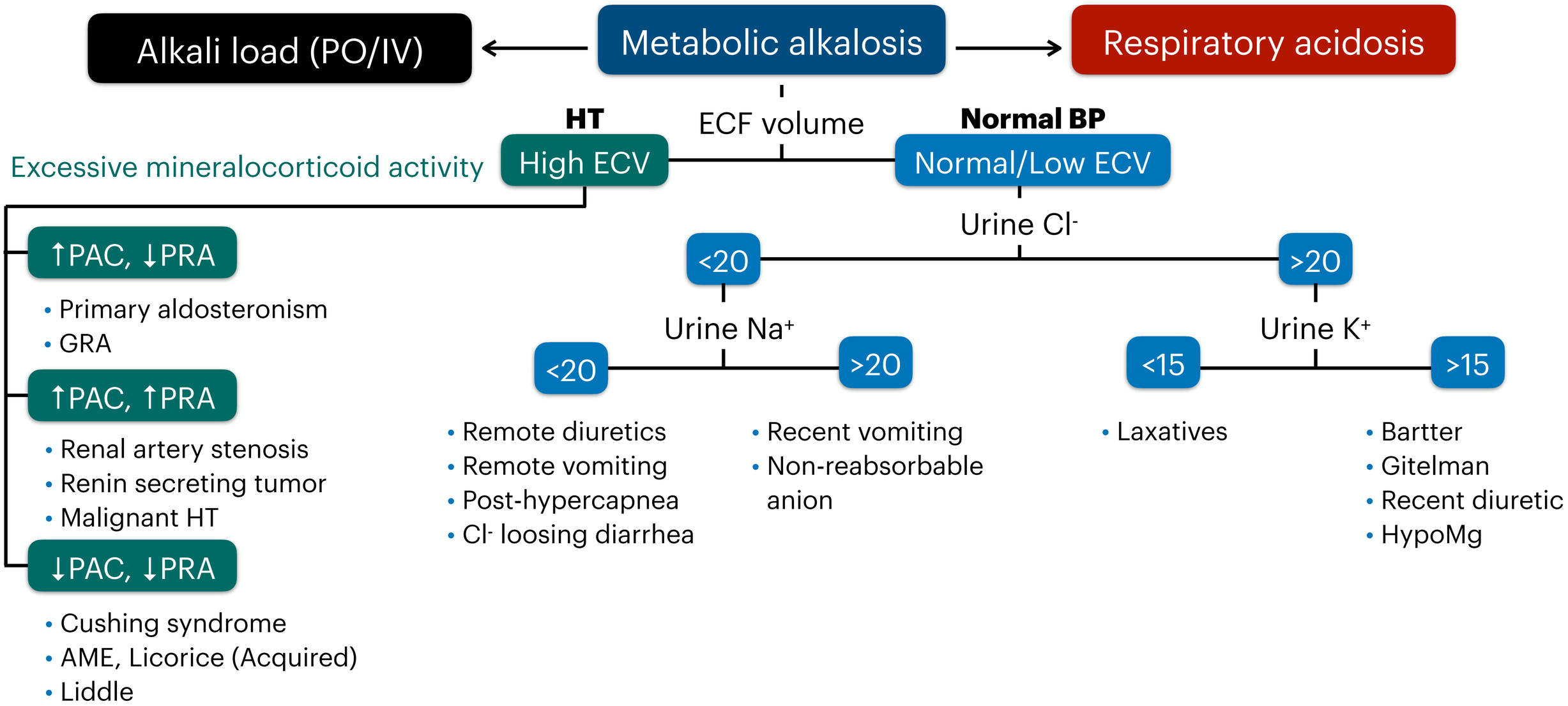
Metabolic Alkalosis

↓Renal HCO_3 excretion

Excretion = Filtration + Secretion - Reabsorption

↓eGFR	↓Tubular secretion	↑Tubular reabsorption
• AKI • CKD	**↓β-Intercalated cell** - ↓Distal Urine Cl^- - Tubular cell dysfunction	• Volume depletion (↑HCO_3 reabsorption at PCT) • Cl^- depletion (Contraction alkalosis) • HypoK (↑H^+-K^+ ATPase function at α-IC) • Hyperaldosteronism (↑ENac, ↑H^+-ATPase at α-IC)

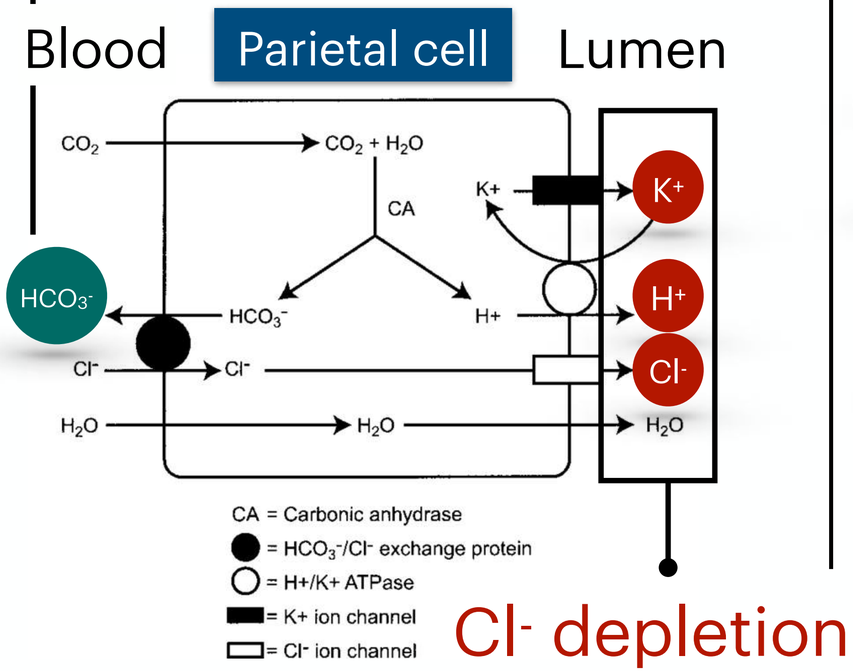
Metabolic Alkalosis (pH > 7.45, Venous [HCO_3] > 30 mmol/L)



Metabolic Alkalosis (pH > 7.45, Venous [HCO_3] > 30 mmol/L)

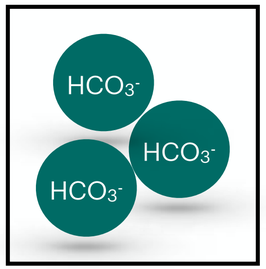
Vomiting (Recent Vs Remote)

Metabolic alkalosis



Cl- depletion

HCO3 excretion

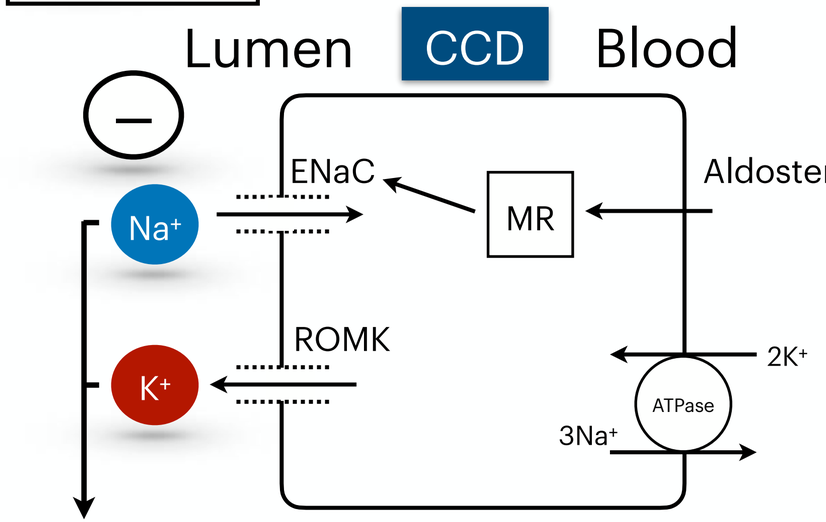


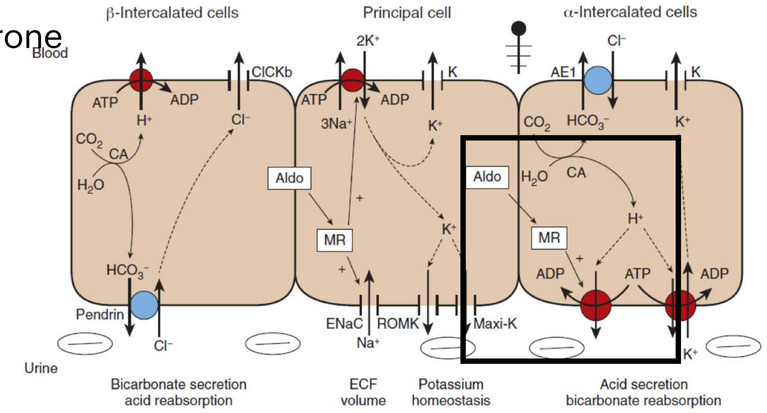
High

Low

Vomiting	Na^+	K^+	Cl^-	pH
Recent	↑	↑	↓	↑
Remote	↓	↓	↓	↓

Paradoxical aciduria





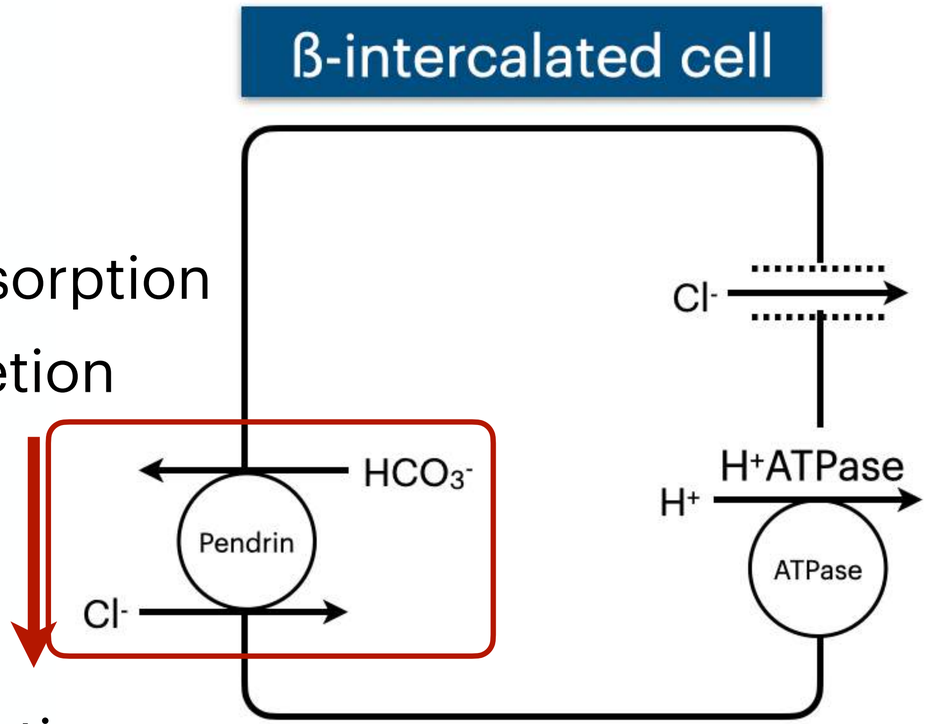
Metabolic Alkalosis (pH > 7.45, Venous [HCO_3] > 30 mmol/L)

Post-hypercapnea

Chronic hypercapnea

↑pCO_2

- ↑HCO_3 reabsorption
- ↓HCO_3 excretion



- ↓Cl^- reabsorption

Hypercapnia is corrected

↓pCO_2

HCO_3 excretion inability due to Cl- depletion !!!

Metabolic Alkalosis (pH > 7.45, Venous [HCO_3] > 30 mmol/L)

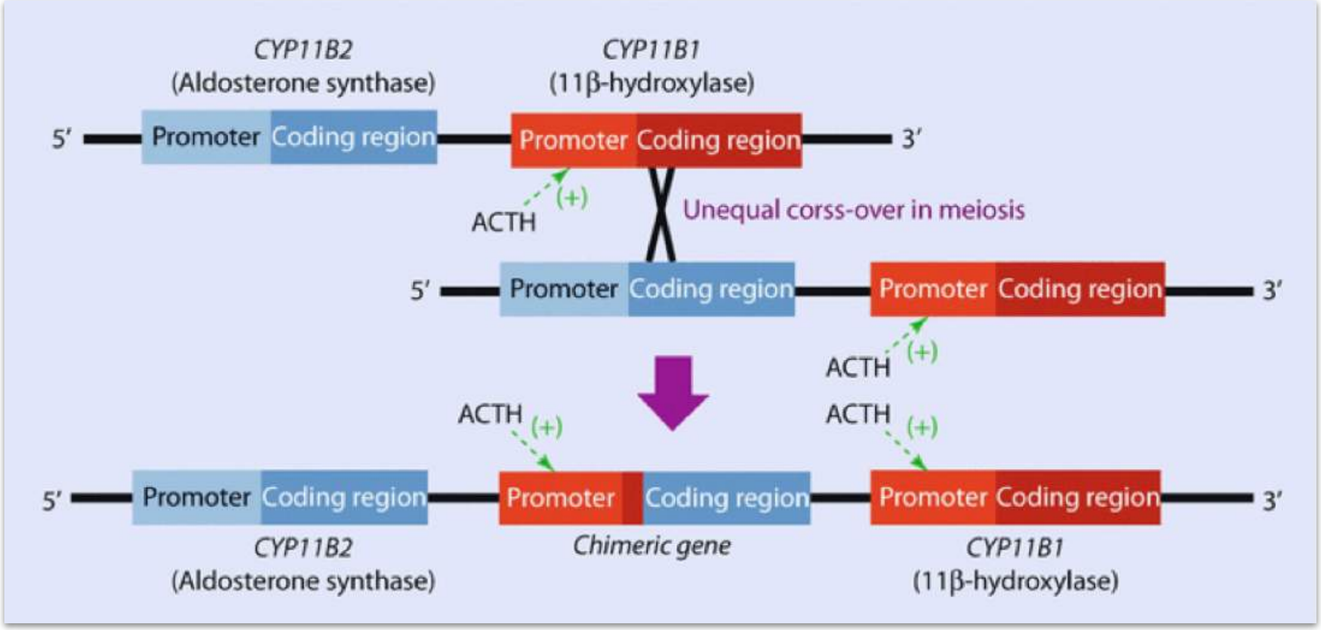
Laxative abuse

Secretion	Electrolyte (mEq/L)					
	Na^+	K^+	Cl^-	...	H^+	Rate (mL/day)
Salivary	50	20	40	30	–	100 to 1000
Basal gastric	100	10	140	–	30	1000
Stimulated gastric	30	10	140	–	100	4200
Bile	140	5	100	–	–	500 to 1000
Pancreatic	140	5	75	–	–	1000
Duodenum	140	5	80	–	–	100 to 2000
Ileum	140	5	70	–	–	100 to 2000
Colon	60	70	15	–	–	–

- Unclear mechanism
- Suspected from K^+ loss
  - ✓↑Intracellular acidosis (transcellular H^+/K^+ exchange)
  - ✓↑H^+/K^+ ATPase at α-IC at CCD
  - ✓↑Ammonia production (↑NH_4^+) → ↑NH_4^+ excretion
- Maintained by volume depletion

Metabolic Alkalosis (pH > 7.45, Venous [HCO_3] > 30 mmol/L)

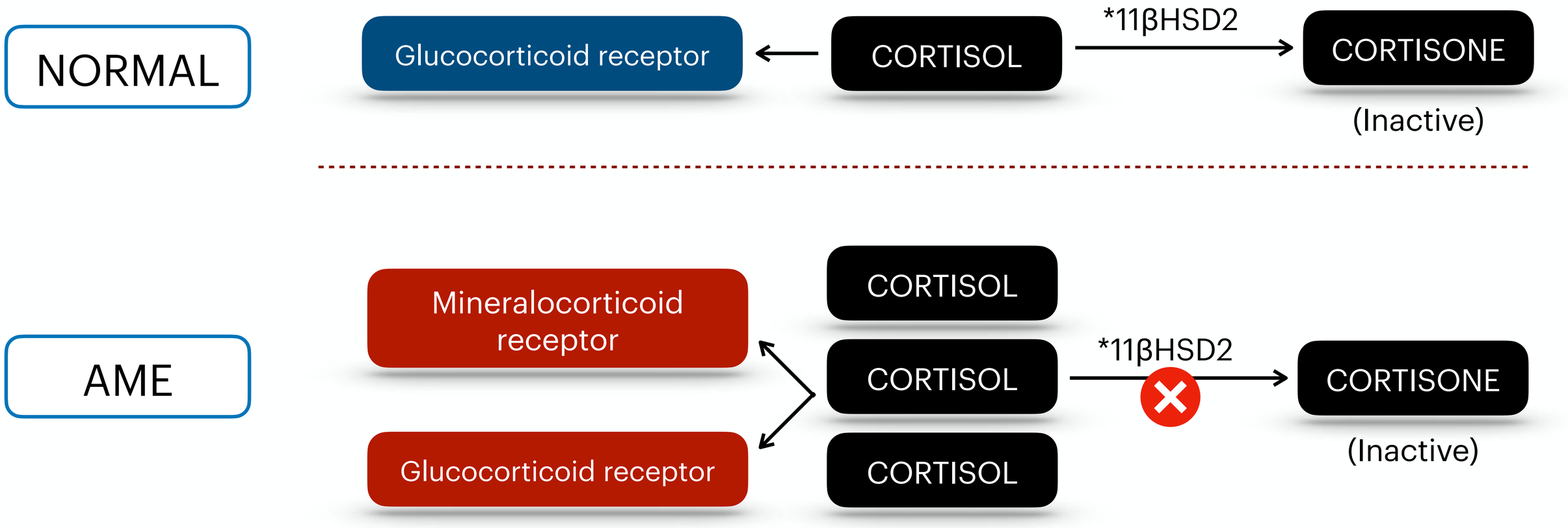
Glucocorticoid Remediable Aldosteronism (GRA)



- **Autosomal dominant**
- **Etiology:** Chimeric gene duplication
- Unequal crossing over between promotor
  - ✓ CYP11B1 gene: encoding **11β-Hydroxylase**
  - ✓ CYP11B2 gene: encoding **aldosterone synthase**
- **ACTH —(+)→ Aldosterone production**
- **Dx:** Dexamethasone suppression test
- **Rx:** Glucocorticoid, Spironolactone

Metabolic Alkalosis (pH > 7.45, Venous [HCO_3] > 30 mmol/L)

Apparent Mineralocorticoid Excess (AME)



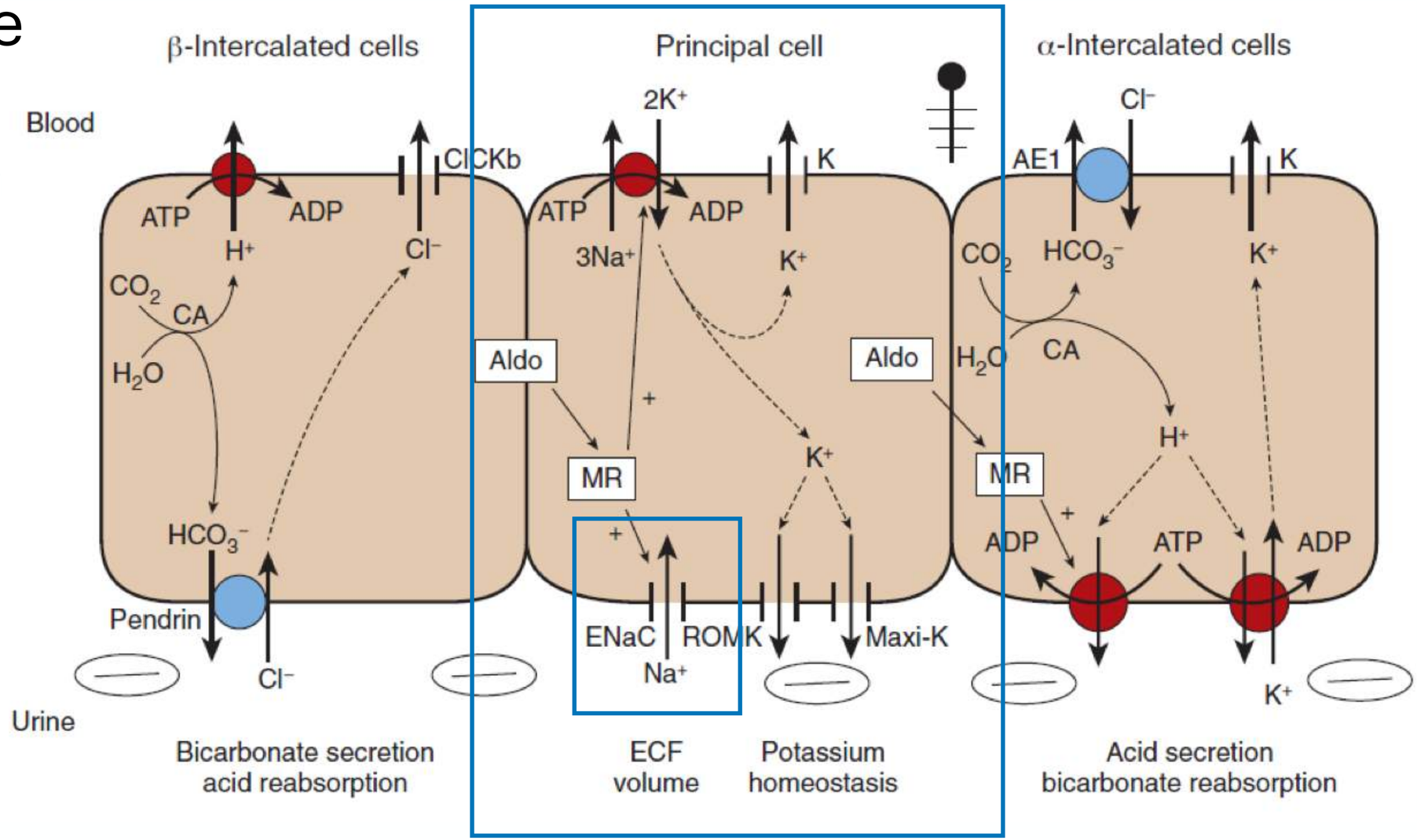
Metabolic Alkalosis (pH > 7.45, Venous [HCO_3] > 30 mmol/L)

Liddle's syndrome

ENaC gain function

Rx: ENaC inhibitor

Amiloride
Pentamidine
Triamterene
Trimethoprim



Case 2:

An 18-year-old woman presents with proximal muscle weakness for 2 weeks. Her blood pressure is **120/80** mmHg and her pulse rate is 80 beats/min. Physical examination revealed proximal muscle weakness of all extremities. Other findings are unremarkable.

LAB:

- Na 136 mmol/L **K 2.8** mmol/L Cl 90 mmol/L **HCO3 38** mmol/L
- BUN 15 mg/dL Cr 0.58 mg/dL, eGFR 113.2 ml/min/1.73m^2
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- WBC 6500/mm^3 (N80% L10%) Hct 35% Plt 250000/mm^3

What is the **MOST** likely cause of her abnormal condition?

A. Gitelman syndrome

B. Bulimia nervosa

C. Recent diuretic use

D. Liddle syndrome


NEPHROLOGY PGH
POLICE GENERAL HOSPITAL
Thank you
#AlwaysNephroPGH