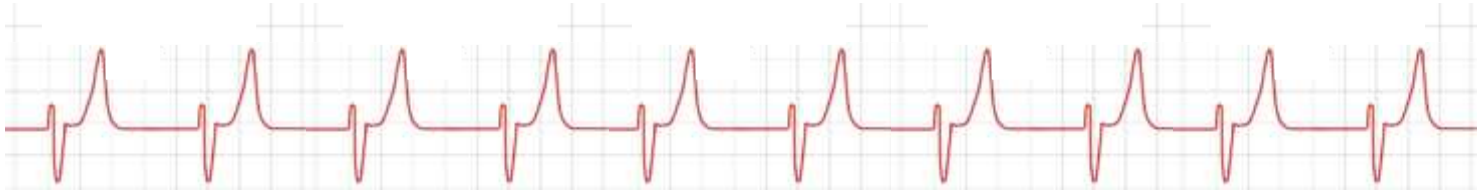
The Forgotten Killers:
Life-threatening electrolyte disbalances (Part I)



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Bucharest, 16th March 2012

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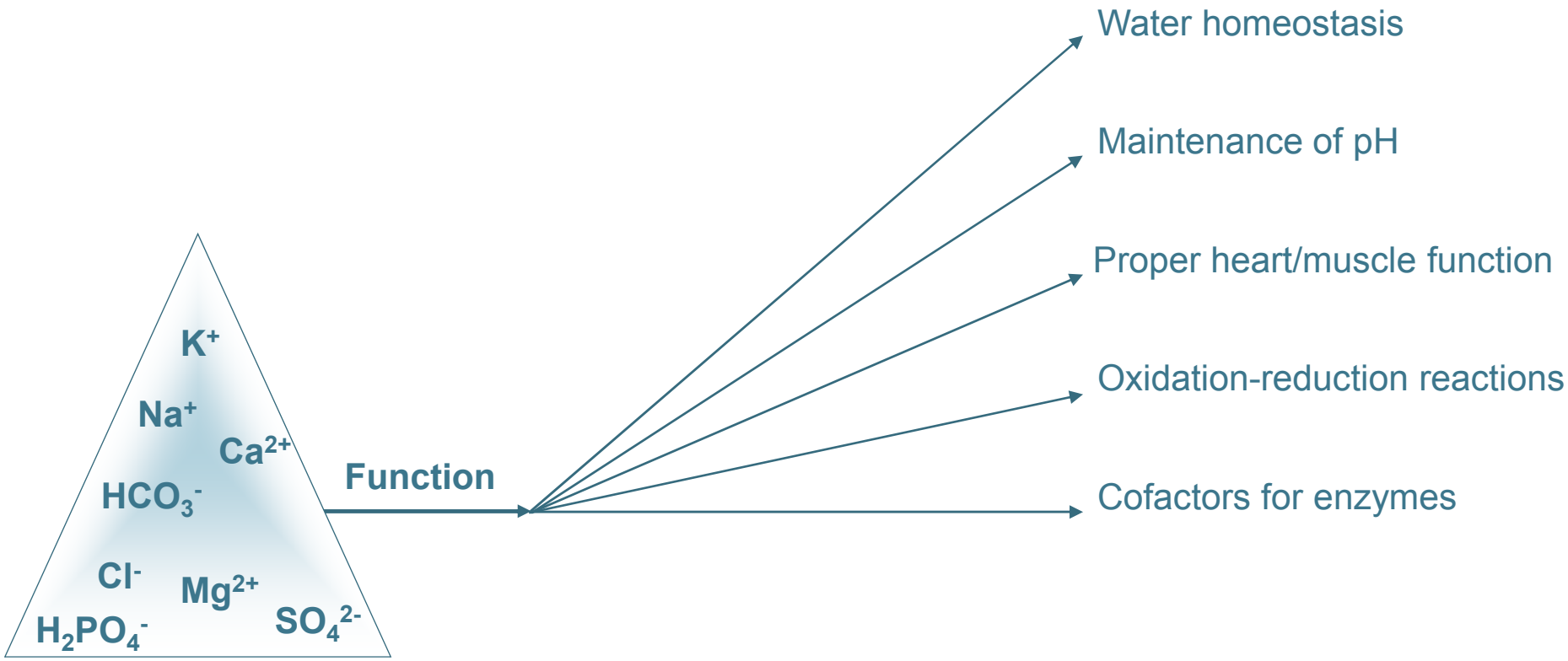
Why are electrolytes to important for the body function?



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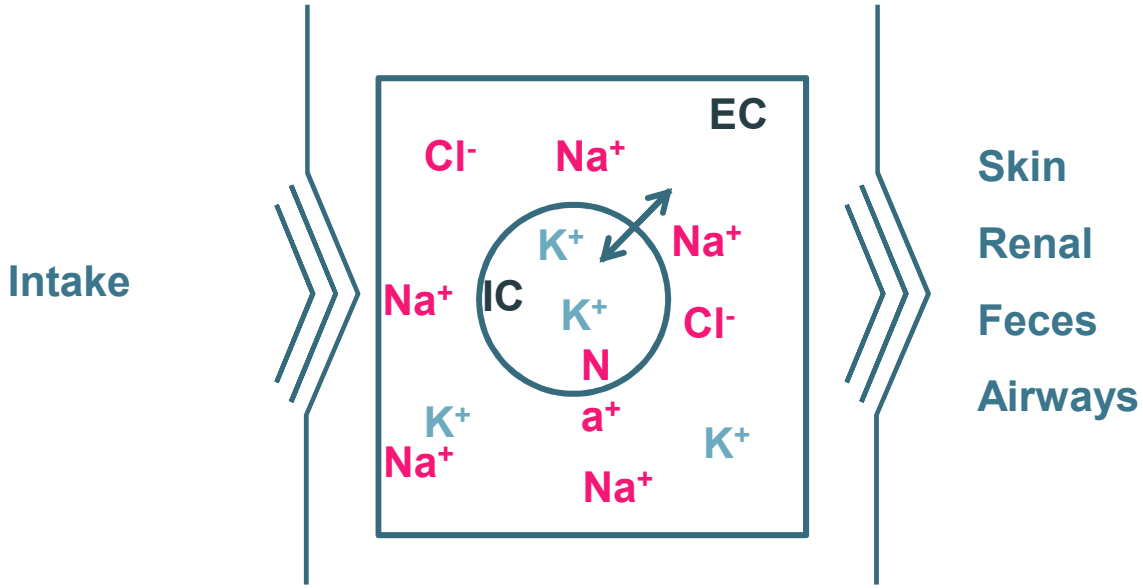
How is electrolyte concentration regulated in the body?



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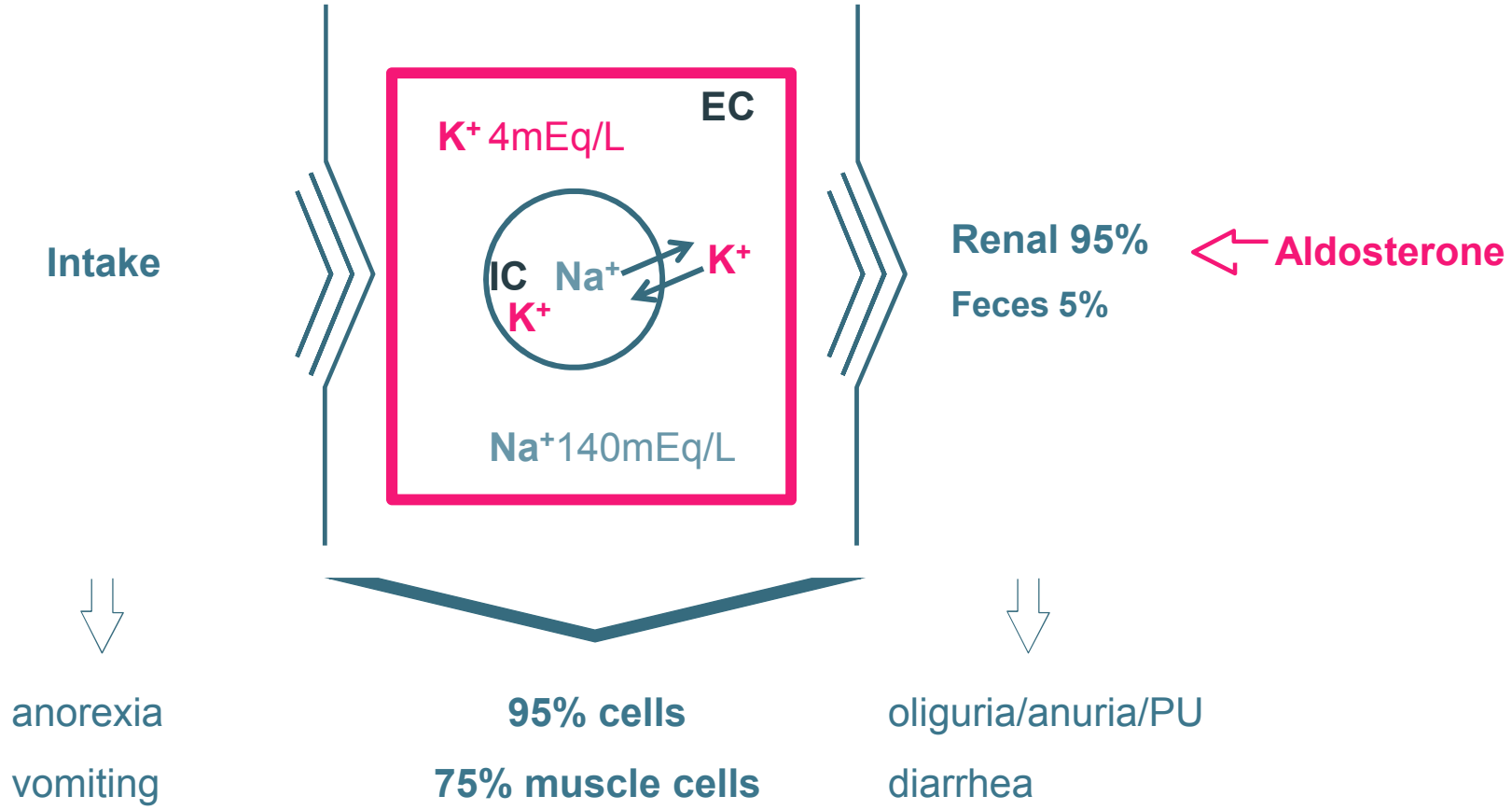
Potassium: one of the most important electrolytes in the body



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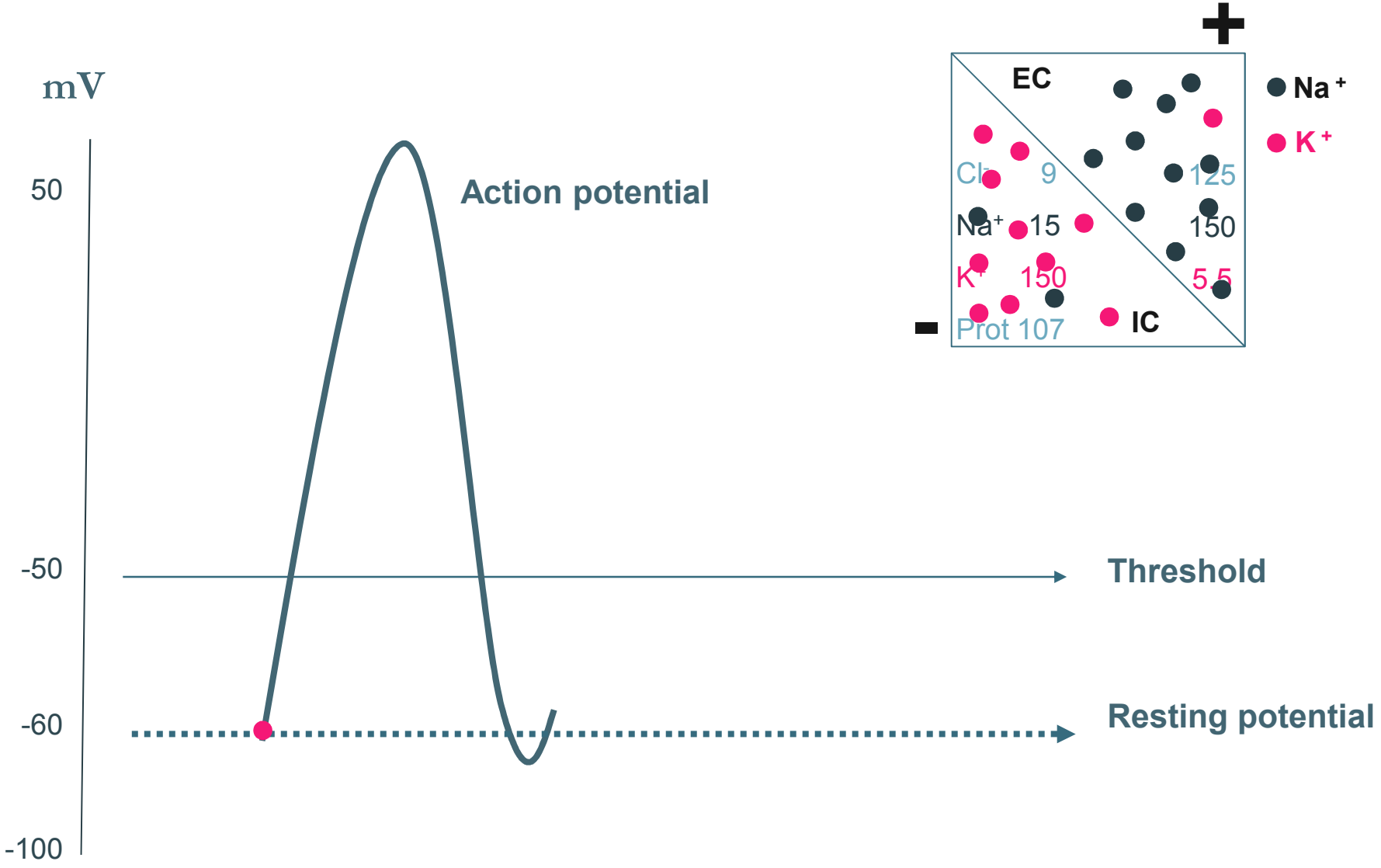
The membrane potential: the most important function of Potassium



Hyperkalemia and hypokalemia are life-threatening

Normal values: 3.5 - 5.5 mEq/L (mmol/L)

Danger values:

- **<2.5 mEq/L**
- **>7.5 mEq/L**

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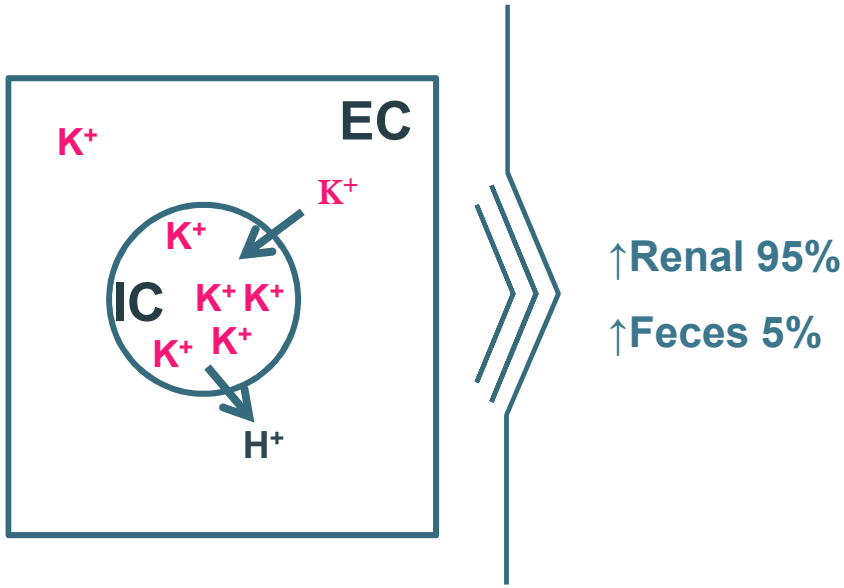
Prolonged anorexia the most common cause of hypokalemia

Electrolyte concentration (mEq/L)	Na	K	Cl
Lactated Ringer's	130	4	109
Ringer's	147	4	156
Normal Saline	154	-	154



↑**Renal 95%**

↑**Feces 5%**

anorexia

vomiting

iatrogenic!!

shift EC → IC

Insulin therapy

chronic renal failure

diuretics

diarrhea

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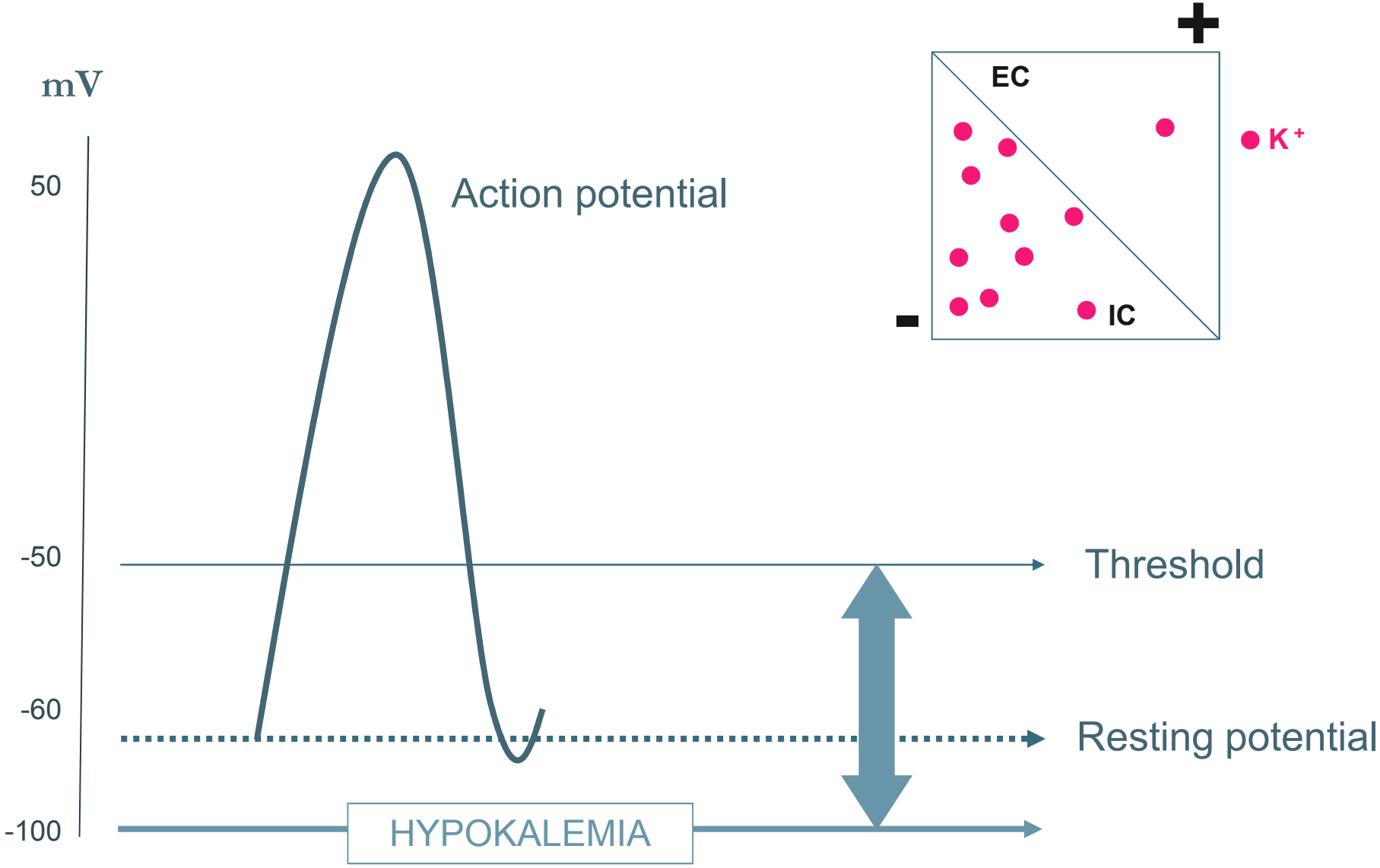
Increase of membrane resting potential due hypokalemia



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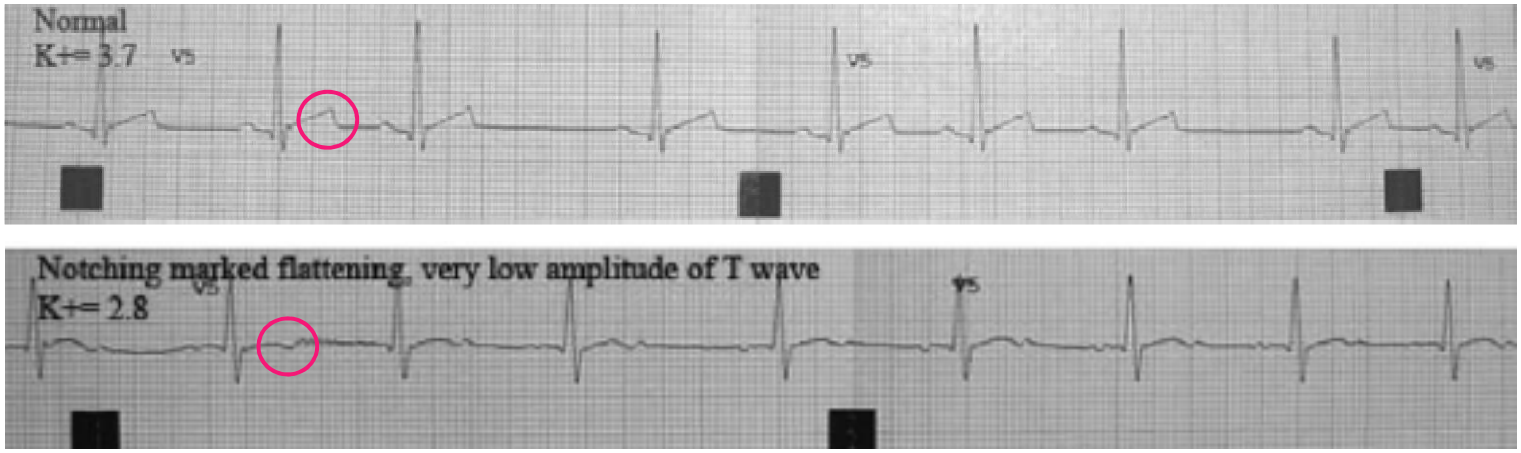
Cardiac dysrhytmias: most important consequence of hypokalemia

Cardiac arrhythmias

- Depressed T-wave amplitude
- Depressed ST segment
- Prolonged QT interval
- Prominent U wave
- Arrhythmias: supraventricular and ventricular



Qualitative relationship between plasma potassium leves and QT interval in beagle dogs. G. Haton et al . Laboratory animals (2007) 41, 204-217

Cats are more susceptible to the effects of hypokalemia

Hypokalemic Polymyopathy

- Potassium < 3.5mEq/L
- CK 10-30x

Hypokalemic Nephropathy

- Azotemia
- Impaired renal function
- Tubulointerstitial nephritis

Picture : http://medical-dictionary.thefreedictionary.com/feline+hypokalemic+polymyopathy

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What would happen with „Tiger“ if we forget to measure Potassium concentration

- 5y, ♂ neutered, ESH cat
- Polidypsia since 10 days
- Lethargy since 5 days

Clinical Signs

- Generalized weakness, lethargy
- Temperature 36.1°C
- Treatment with infusion during 2 days by local veterinary

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Whithout the Potassium measurement we would treat „Tiger“ just like a hypoglykemic patient

Parameter	Patient	Reference interval	Unit
Hematocrit	47.1	27-47	%
Glucose	17	55-100	md/dl
ß-Hydroxybutyrat	1.19	<1	mmol/L
Creatinine	4.1	<1.6	mg/dl
TP	8.42	6-7.5	g/dl
Albumin	3.77		g/dl
ALT	319	<100	U/l
CK	3161	<200	U/l

Hemolytic plasma ++

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Many possible diagnosis in the case of „Tiger“

1. Treatment Diabetic Ketoacidosis

2. Feline Kaliopenic Nephropathy-Polymyopathy Syndrome

- Predisposing factors: low dietary K, dietary acidification, CRF
- Clinical signs: cervical ventroflexion, generalized muscle weakness, signs of renal failure
- Diagnosis: hypokalemia, azotemia, metabolic acidosis

Minerals

Calcium (%)	0.99
Chlorine (%)	0.61
Copper (mg/kg)	15.0
Iodine (mg/kg)	3.4
Iron (mg/kg)	195.0
Magnesium (%)	0.09
Manganese (mg/kg)	73.0
Phosphorus (%)	0.85
Potassium (%)	0.6

Minerals

Calcium (%)	0.15
Chlorine (%)	0.3
Copper (mg/kg)	2.4
Iodine (mg/kg)	0.8
Iron (mg/kg)	27.0
Magnesium (%)	0.01
Manganese (mg/kg)	2.2
Phosphorus (%)	0.14
Potassium (%)	0.28

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Potassium supplementation in hypokalemic patients

Serum K^+ (mEq/L)	mEq KCL to add to 250mL fluid	Max fluid infusion rate (mL/kg/hr)
<2.0	20	6
2.1 – 2.5	15	8
2.6 – 3.0	10	12
3.1 – 3.5	7	18
3.6 – 5.0	5	25

Rate of IV Potassium administration: max 0.5mEq/kg/h

In: Fluid, electrolyte, and acid-base disorders in small animal practice, (pp107) S.P DiBartola

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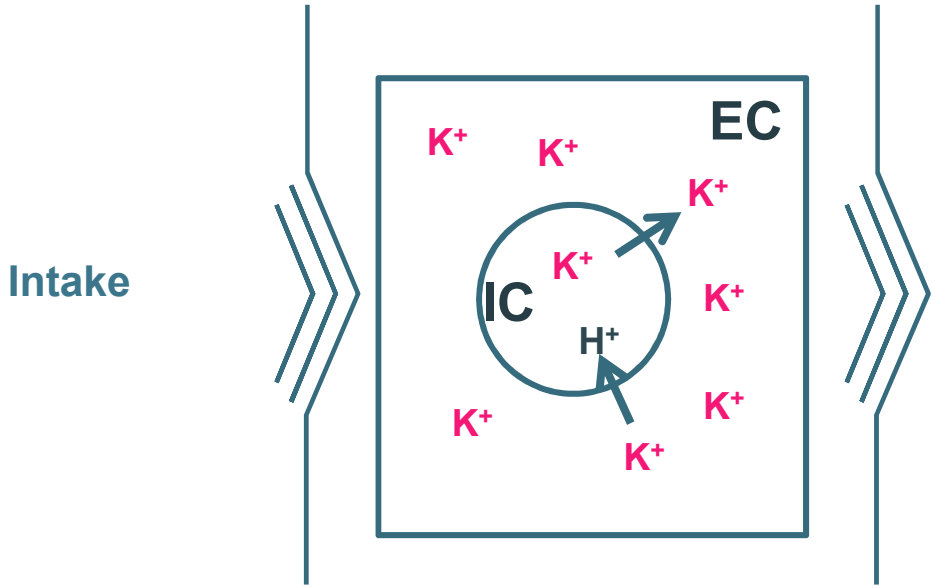
Decreased urinary potassium excretion most important cause of hyperkalemia



iatrogenic!!

Shift IC → EC

anuria/oliguria

↓renal excretion

Rule out pseudohyperkalemia!!!!

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Don‘t panic: first rule out pseudohyperkalemia

anamnesis	+	clinical signs	+	lab results
⇩		⇩		⇩
Akita, english springer spaniel, neonates		asymptomatic		thrombocytosis leukocytosis

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EDTA anticoagulant most common preanalytical error in the measurement of potassium concentration

Test		Heparin	Reference interval
Urea	27	28	20-40 mg/dl
Crea	0.9	1.0	bis 1.2 mg/dl
AP	111	364	bis 190 U/L
ALT	50	39	bis 40 U/L
Lipase	254	258	bis 250 U/L
Ca	0.2	2.6	2.4-3.0 mmol/L
K	29	4.1	3.6-5.6 mmol/L
Na	148	152	140-152 mmol/L
Cl	113	116	98-120 mmol/L

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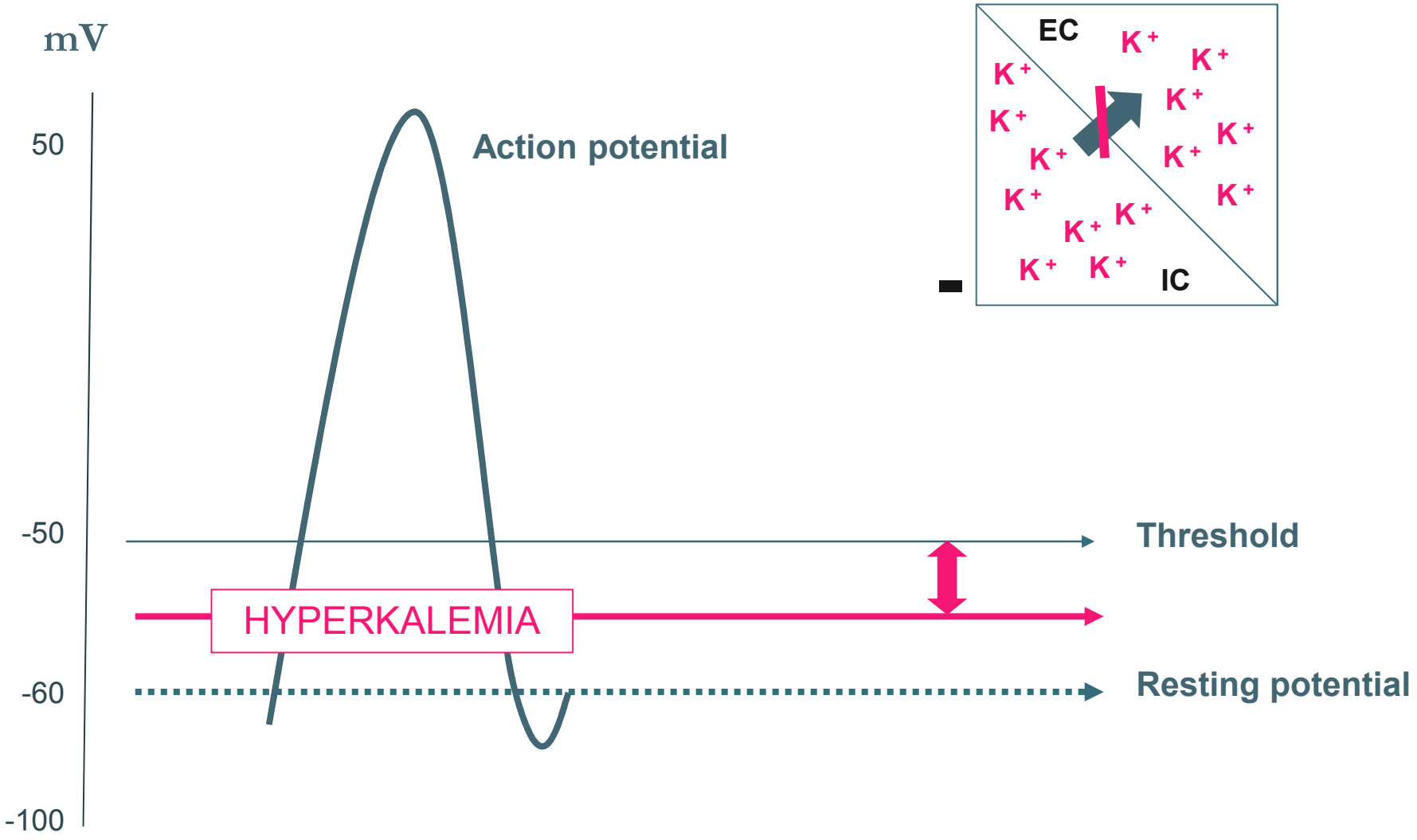
Decrease of membrane resting potential due hyperkalemia



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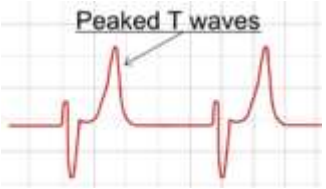
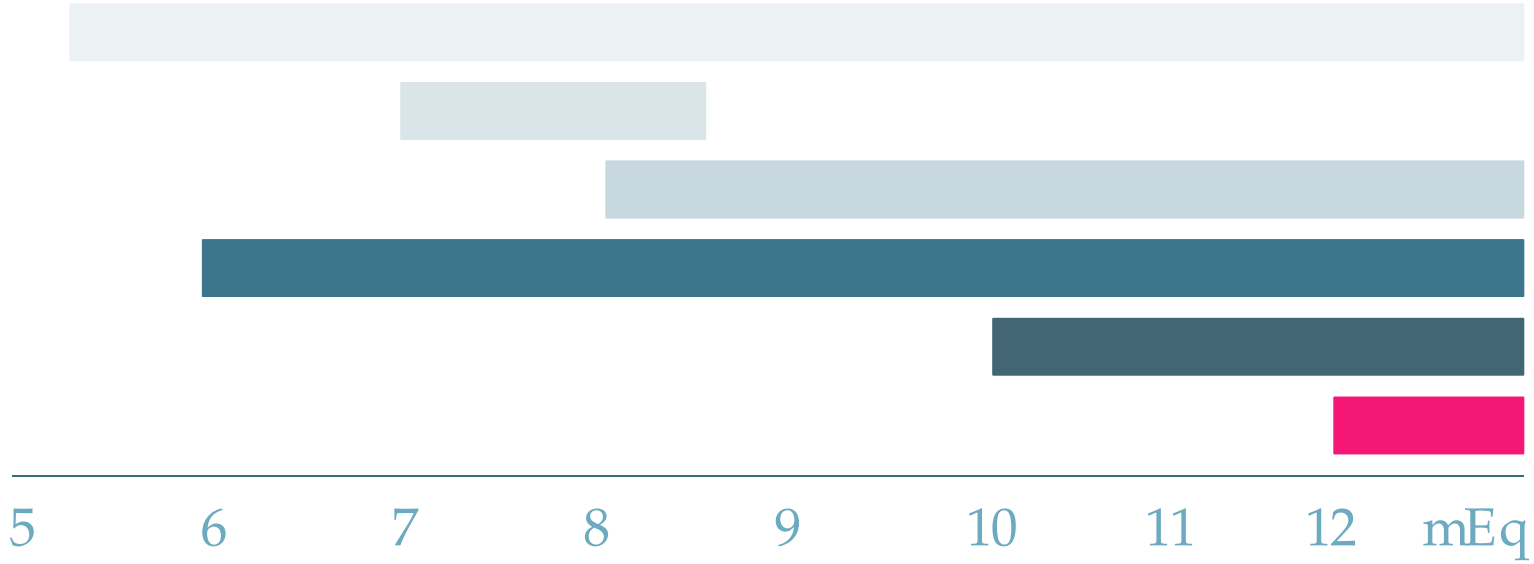
Progressive ECG changes develops with worsening hyperkalemia





- ↑ rate of repolarization → peaked, tented T wave, shortened Q-T interval
- Slowed conduction in atria → flattened P wave
- Conduction through atria fails → P wave disappears
- Progressive slowing of intraventricualr conduction → QRS widens
- Activation of ectopic pacemakers → irregular ventricular rhythm
- Ventricular fibrillation or asystole

In: Cardiovascular System Disorders in Small Animal Internal Medicine, RW Nelson, CG Couto

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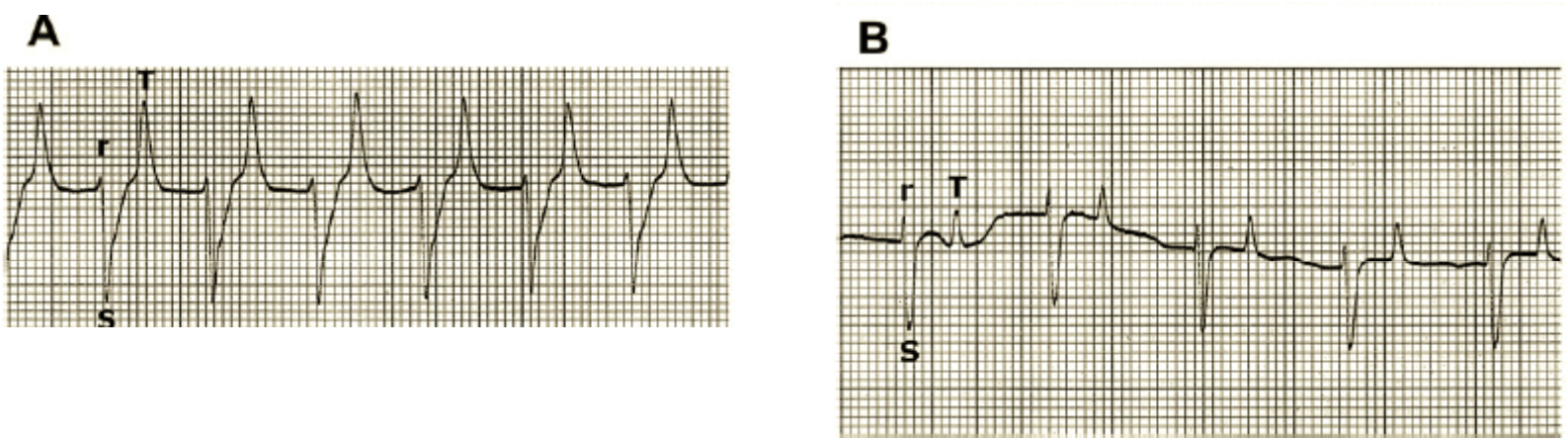
Poor correlation between ECG changes and potassium concentration



Cat A & B (urethral obstruction) and hyperkalemia (10.5mEq/L)

- **> 5.5 - 7 mEq/L** peaking T wave, shortening QT interval
- **7.1 – 8.5 mEq/L** widening QRS complex, prolongation PR interval, loss P wave, atrial standstill
- **8.6 – 12 mEq/L severe** indistinctly fusion of QRS complexes and T waves into a sine-wave
- **> 12 mEq/L critical** ventricular fibrillation and/or asystole

Feline arrhythmias: an update. E. Coté (2010) Vet Clin Small Anim 40, 643-650

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What would happen with „Simba“ if we forget to measure Potassium concentration

- 5y, ♀ spayed, mix breed
- Vomitous since 3 weeks
- Decrease food and water ingestion sometimes
- Increased serum urea and creatinine concentration

Clinical Signs:

- Lethargy
- Heart rate 60bpm, weak heart sounds
- Muscle atrophy: hind limbs and head

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Unremarkable hematological results

Parameter	Patient	Reference interval	Unit
RBC	7.56	5.5-8	10^6/µl
HCT	45	37-55	%
HGB	19.5	12-18	g/dl
MCV	59.5	60-77	fl
MCH	21	19-24.5	pg
MCHC	35.3	31-34	%
WBC	11.68	6-15	10^3/µl
Neut. Gran.	7.65	3.3-11.25	10^3/µl
Lymphozyten	2.71	0.78-4.5	10^3/µl
Monozyten	0.61	0.5	10^3/µl
Eos. Gran.	0.65	0.8	10^3/µl

Microscopic examination: unremarkable

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Whithout the Potassium measurement we would treat „Simba “ just like a renal patient

Parameter	Patient	Reference interval	Unit
Glucose	103	55-90	mg/dl
Fruktosamin	259	< 370	µmol/l
Urea	267	20-40	mg/dl
Creatinine	6.6	0.4-1.2	mg/dl
TP	7.25	6-7.5	g/dl
Albumin	3.37	2.6-4.7	g/dl
AP	53	<190	U/l
ALT	78	<80	U/l
Triglycerids	44	50-100	mg/dl
Cholesterol	179	125-250	mg/dl
Amylase	2104	<1650	U/l
Lipase	22	<125	U/l
CK	164	<250	U/l

→ **Azotemia** → Prerenal / Renal / Postrenal

History + Clinical Signs + Urinalysis (SG)

Na:K Ratio = 15.9

Na:K < 27: most common causes

Table 1. Serum sodium, potassium, and Na:K ratio values and agnoses listed in descending order of ratio values.

odium (meq/liter)*	Potas-sium (meq/liter)†	Na:K ratio	Primary diagnosis
148	6.2	23.87	renal failure
148	6.2	23.87	mammary tumor
143	6.0	23.83	hypoadrenocorticism
152	6.4	23.75	renal failure
147	6.2	23.7	behavioral disorder
147	6.3	23.33	renal failure
140	6.0	23.33	thyroid adenocarcinoma
149	6.4	23.28	heart failure
149	6.4	23.28	hypoadrenocorticism
139	6.0	23.17	hemagiosarcoma
127	5.5	23.09	pyometra
138	6.0	23.00	ketoacidosis, diabetes
146	6.4	22.81	pancreatitis
133	6.9	22.17	heart failure
145	6.6	21.97	renal failure
145	6.6	21.97	mushroom poisoning
146	6.7	21.79	renal failure
148	6.9	21.45	renal failure
143	6.8	21.03	renal failure
126	6.1	20.66	renal failure
136	6.6	20.66	ruptured bladder
121	5.9	20.51	pancreatitis
138	7.0	19.71	parasitism
138	7.0	19.71	renal failure
119	6.2	19.19	hypoadrenocorticism
146	7.8	18.72	renal failure
123	6.9	17.82	renal failure
130	7.3	17.81	hypoadrenocorticism
138	8.0	17.25	ketoacidosis, diabetes
142	8.7	16.32	perineal hernia, incarcerated bladder
134	9.0	14.89	hypoadrenocorticism
129	9.0	14.33	hypoadrenocorticism, renal failure
129	9.0	14.33	hypoadrenocorticism
128	9.3	13.76	hypoadrenocorticism

* Reference range = 141–153 meq/liter.
† Reference range = 4.1–5.3 meq/liter.

Na:K < 27; N=39

26% urinary disease

16% parasitism

1 case hypoadrenocorticism Na:K 15,75

Na:K < 24; N=34

41% urinary tract/renal disease

24% hypoadrenocorticism

Na:K < 15

100% hypoadrenocorticism

Table 1. Diagnosis listed in descending order of Na:K ratio values and its respective concentrations (mEq/L) of serum sodium and potassium

Sodium*	Potassium*	Na:K ratio	Primary diagnosis
132	4.9	26.94	pancreatitis
150	5.7	26.32	patellar luxation
147	5.6	26.25	pancreatitis
152	5.8	26.21	bacterial pneumonia
146	5.6	26.07	patellar luxation
145	5.6	25.89	abdominal multiple bite wound
137	5.3	25.85	parasitism
139	5.4	25.74	parasitism
149	5.8	25.69	parasitism
150	5.9	25.42	portosystemic shunt
144	5.7	25.26	renal failure
150	6.0	25.00	heartworm infection
150	6.0	25.00	tarsal & metatarsal necrosis
149	6.0	24.83	steroid-induced hepatopathy
140	5.7	24.56	heart failure
152	6.3	24.13	hindlimb paralysis
147	6.1	24.10	preputal inflammation
163	6.8	23.97	urinary bladder & urethra mineralization
148	6.2	23.87	parasitism
107	4.5	23.78	bacterial pneumonia
152	6.4	23.75	pyoderma
140	6.0	23.33	renal failure
146	6.3	23.17	pyometra
148	6.4	23.13	diabetes
140	6.1	22.95	parasitism
150	6.9	21.74	diabetes
143	6.6	21.67	acute nephritis, renal failure
138	6.4	21.56	renal failure
125	5.9	21.19	renal failure
137	6.5	21.08	renal failure
142	7.2	19.72	renal failure
132	6.7	19.70	pyometra
134	7.8	17.18	renal failure
127	7.4	17.16	renal failure
155	9.2	16.85	renal failure
122	7.3	16.71	renal failure
126	8.0	15.75	hypoadrenocorticism, renal failure
112	7.7	14.55	parasitism
143	10.0	14.30	pyoderma

*Reference range=140-152 mEq/L; †Reference range=3.6-5.8 mEq/L [32].

Evaluation of low sodium:potassium ratio in dogs, L. Roth & R.D. Thyler (1999) J Vet Diagn Invest 11:60-64 (left)

The clinical implication of sodium-potassium rtios in dogs. Son-Il Pak (2000) J. Vet. Sci. 1(1), 61-65

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95% of dogs with hypoadrenocorticism have hyperkalemia

Parameter		Reference Interval	Unit
ACTH	2420	< 20	pg/ml
Cortisol basal	< 1.0	1-4	µg/dl
Cortisol 90 Min.	< 1.0	…	µg/dl

⇨ Hypoadrenocorticism

Hyperkalemia 95%; range 4.1-10.8mEq/L (7mEq/L)

Hyponatremia 86%; range 106-155mEq/L (128mEq/L)

Na:K Ratio Normal 27:1 – 40:1

1° hypoadrenocorticism 95% < 27:1, ratio < 15:1

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What would happen with „Isis“ if we forget to measure Potassium concentration

- 11y, ♀ spayed, B. Sennenhund
- Since 2 months polakisuria and dysuria
- Reddish urine

Clinical findings

- Lethargy
- Abdomen: undulation

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Slight changes in the hematological results of „Isis“

Parameter	Patient	Reference interval	Unit
RBC	6.13	5.5-8	10^6/µl
HCT	42.6	37-55	%
HGB	16.5	12-18	g/dl
MCV	69.5	60-77	fl
MCH	26.9	19-24.5	pg
MCHC	38.7	31-34	%
WBC	15.9	6-15	10^3/µl
Neutrophils	12.58	3.3-11.25	10^3/µl
Lymphocytes	1.81	0.78-4.5	10^3/µl
Monocytes	1.27	0.5	10^3/µl
Eosinophils	0.31	0.8	10^3/µl

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Trying to find out origin of Azotemia

Parameter	Patient	Reference interval	Unit
Glucose	107	55-90	mg/dl
Urea	169.7	20-40	mg/dl
Creatinine	4.8	0.4-1.2	mg/dl
TP	8.22	6-7.5	g/dl
Albumin	4.29	2.6-4.7	g/dl
ALT	68	<80	U/l

→ **Azotemia** → Prerenal / Renal / Postrenal

History + Clinical Signs + Urinalysis (SG)

Na:K Ratio = 25

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Cooperation between laboratory findings

Peritoneal Fluid Analysis:

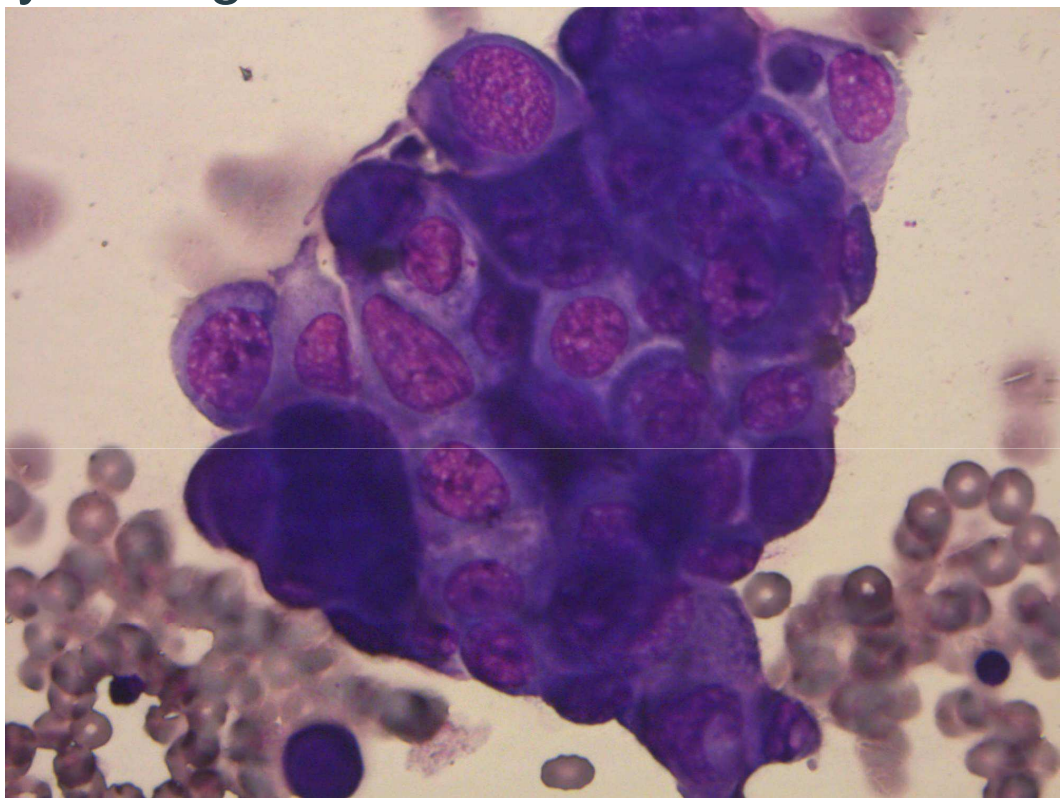
Color: brown-reddish

Total cell count: 890/µl

Total Protein: 0.3g/dl

Cytological Examination:

low cell content, with 90% degenerated neutrophils and 10% mononuclear cells



Parameter	Serum	Effusion	Unit
Urea	169	273.3	mg/dl
Creatinine	4.8	16.3	mg/dl

⇨ **Uroperitoneum**

Treatment of hyperkalemia: step by step

Acute increase (> 6.5mEq/L)

Asymptomatic animals (5.5-6.5mEq/L)

- Discontinue Potassium intake and drugs that promote hyperkalemia
- Treatment of underlying diseases
- Fluid therapy e.g. 0.9% NaCl
- Treatment of hyperkalemia:
  - Calcium gluconate (2-10ml of a 10% solution IV)
  - Glucose (1-2ml/kg 50% dextrose IV)
  - Dialysis

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