Potassium disorders

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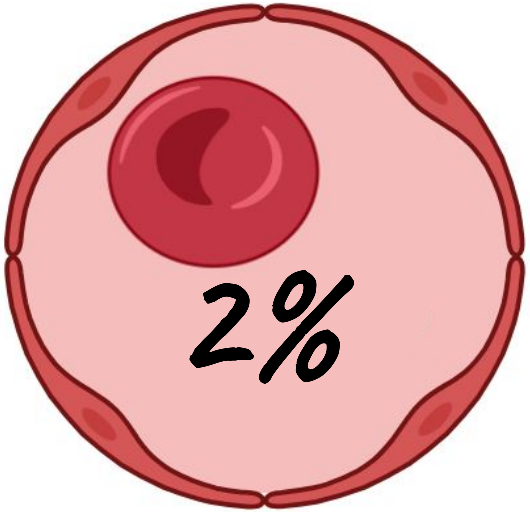
Today's aims

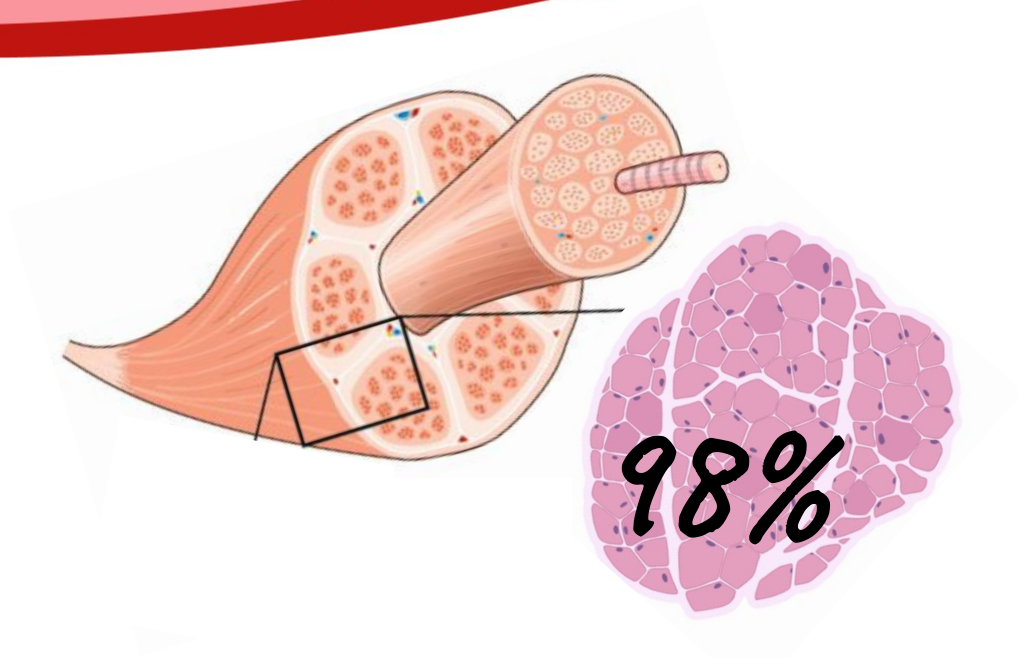
- Potassium homeostasis + clinical relevance
- Dyskalemia
  - Causes in ECC
  - CVS changes
- Treating hyperkalemia
- Potassium supplementation

Potassium homeostasis

Potassium distribution



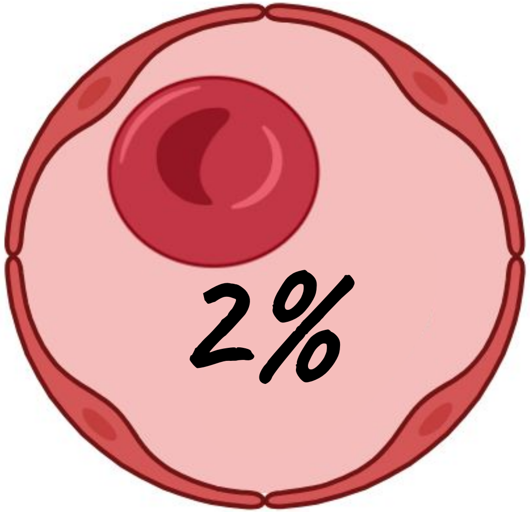
4 mEq/L

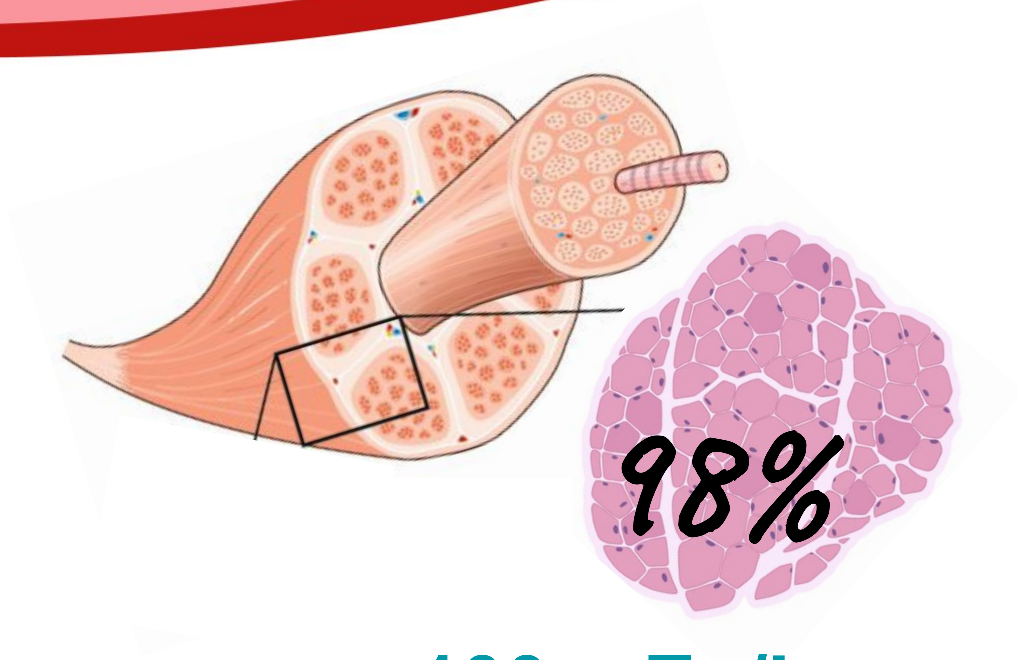


140 mEq/L

Images by biorender.com

Potassium distribution



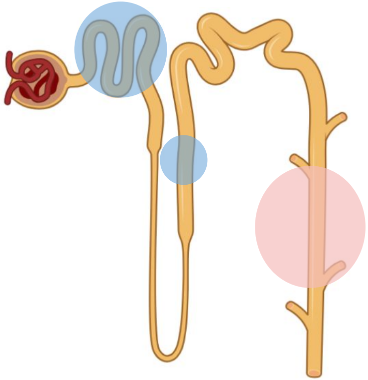


↓ 0.3 mEq/L

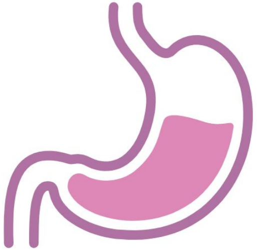
↓ 100 mEq/L

Images by biorender.com

Potassium homeostasis

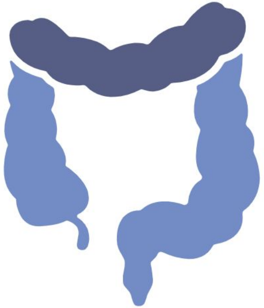


K gain in PT + LOH
K loss in CD

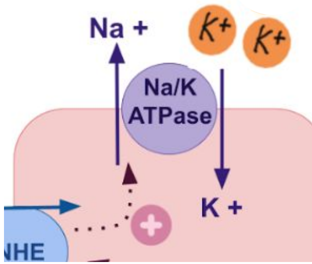


"Feed-forward" maintains K+

Circadian clock augments K loss

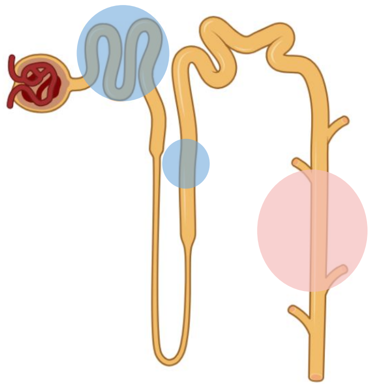


K loss via GIT



Intracellular sequestration

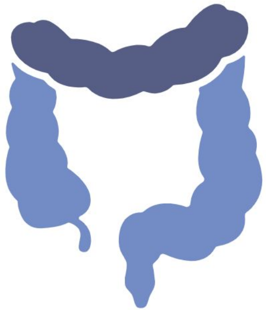
Clinical relevance



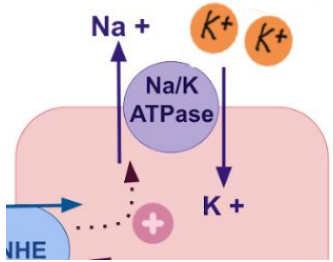
<u>↑ K loss</u>

- High fluid rates
- RAAS activation

AM samples ↓
PM samples ↑



↓ K in GI patients



For hyperK tx

Dyskalemias

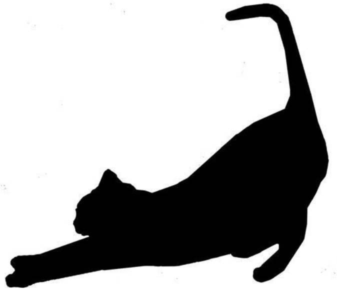
Incidence

doi: 10.1111/vec.12889

Hyperkalemia

8%

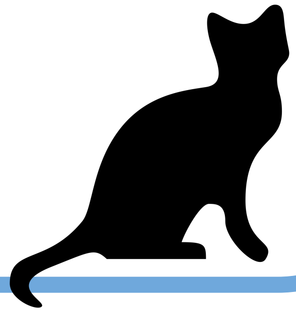
13%



Hypokalemia

18%

27%



Incidence

Hyperkalemia

Hypokalemia

- Mortality
- Cardiac events (e.g. arrhythmias)
- Longer hospitalization

doi: 10.1111/vec.12889
doi: 10.1186/s13054-019-2679-z
doi: 10.1186/s13613-019-0573-0
doi:10.1136/bmjopen-2022-068387

Incidence

Hyperkalemia

Hypokalemia

- Faster correction hyperK, improved mortality
- Lower variability K in hosp, less mortality

doi: 10.1016/j.ajem.2019.12.012
doi: 10.1186/s13613-019-0573-0

Break

Hyperkalemia

General classification of hyperkalemia

Mild
5-5.9 mEq/L

Moderate
6-6.9 mEq/L

Severe
>7 mEq/L

ECG
> 6.0 — — — — — — — — →

Interventions
> 6.5 ————————→

doi: 10.1016/j.jemermed.2018.09.007

Common causes of hyperkalemia

Urinary tract disease

1

AKI	Post-renal (ureteral, urethral)

2

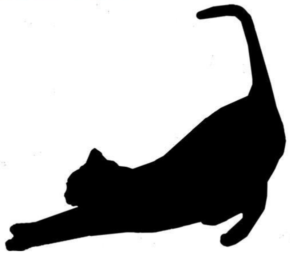
Endocrine (HypoA)

* Note: There many other causes*

doi: 10.1111/vec.12889

Moderate to severe hyperk in diseases

PMID: 37138712
doi:10.1111/vaa.12250
doi: 10.1111/jvim.16375
doi: 10.1111/jsap.13661
doi:10.1111/j.1476-4431.2006.00189.x
doi:10.14202/vetworld.2021.2002-2008



AKI
K> 5.3 in 22%

HypoA
K> 6.5 in 40%

Ureteral obstruction 35%

Urethral obstruction 25%

Other relevant causes of hyperk

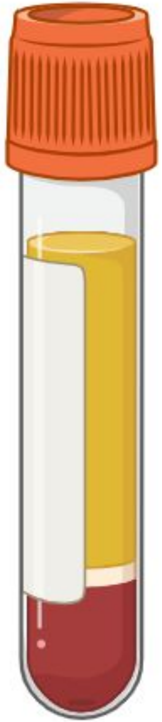
Unknown hyperK in anesthesia
(Rare:19 cases/7yrs)

RAAS inhibition
ACEi
ATII inhibitors
Spironolactone

Aminocaproic acid?

doi: 10.1016/j.vaa.2022.12.005
doi: 10.1161/JAHA.120.017748
doi: 10.1016/S0272-6386(99)70234-9

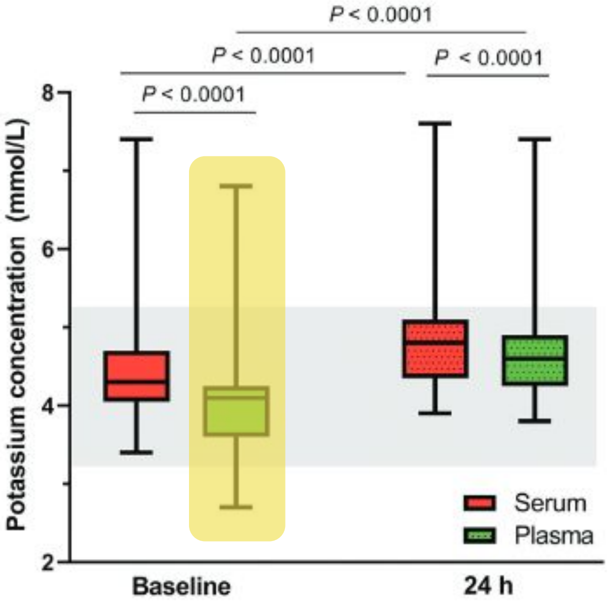
Pseudohyperkalemia



- Serum samples
- Thrombocytosis > 1 million
- Leukocytosis >100,000

doi:10.1007/s12291-020-00889-3
doi: 10.1111/j.1939-1676.1989.tb00328.x

Pseudohyperkalemia



Serum
0.4 mEq/L
higher

24h later
0.4 mEq/L
higher

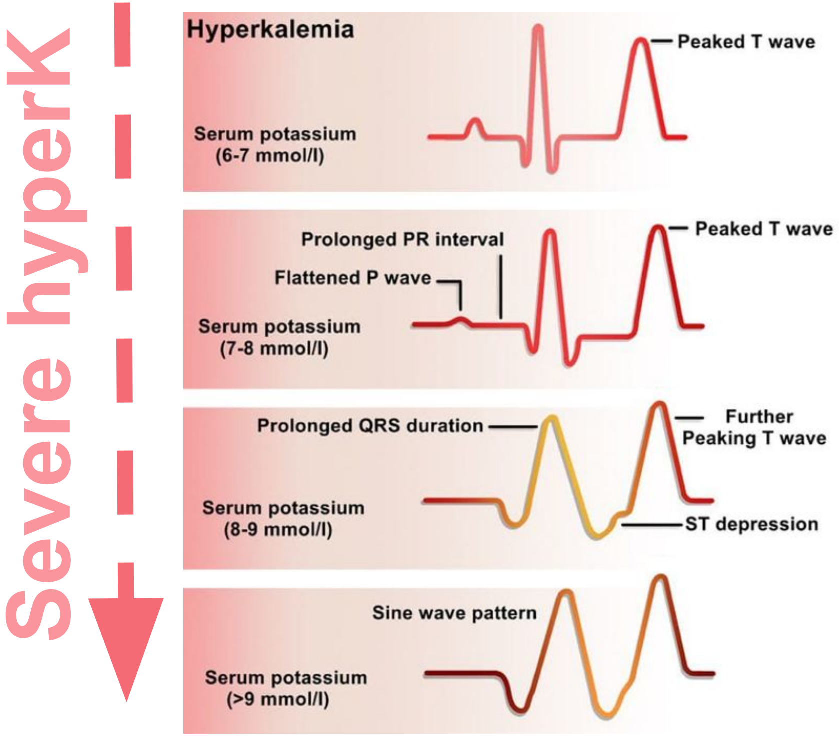
doi: 10.2460/javma.20.09.0530

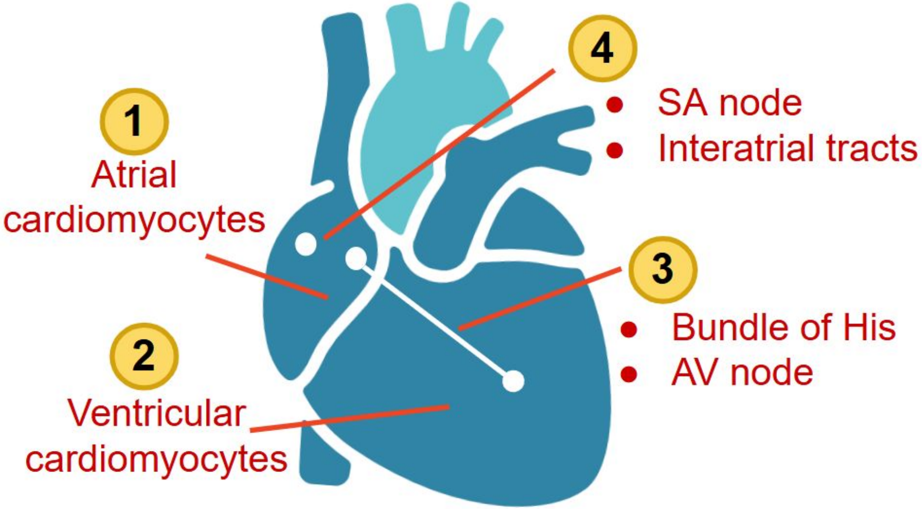
Hyperkalemia and the heart 🧡

- ECG changes common in hyperK
  - 54-67% hyperK dogs + cats

doi: 10.1111/vec.12889
doi: 10.1111/j.1476-4431.2007.00268.x
doi: 10.14202/vetworld.2021.2002-2008
doi: 10.1177/1098612X221127234

HyperK ECG changes





doi: 10.3389/fphys.2013.00228

Sine-Wave pattern

- Merging of wide QRS complexes + T waves
- **Impending v-fib + asystole**

PMID: 22571204

ECG not always consistent

- Orderly trend in experiments
- Not always the same trend clinically
- Any arrhythmia is possible
  - AV blocks, a-fib, BBB

Break

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Mild
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Moderate
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Severe
>7 mEq/L

ECG
> 6.0 – – – – – – – – →

Interventions
> 6.5 ————————→

doi: 10.1016/j.jemermed.2018.09.007

Management of hyperkalemia

Calcium Gluconate

β2 agonists

Sodium Bicarbonate

Dialysis

Insulin + Dextrose

doi: 10.1016/j.phrs.2016.09.039
doi: 10.1016/j.ajem.2019.12.012
doi: 10.1016/j.jemermed.2018.09.007
doi: 0.1002/14651858.CD010344.pub2

Management of hyperkalemia

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Dialysis

doi: 10.1016/j.phrs.2016.09.039
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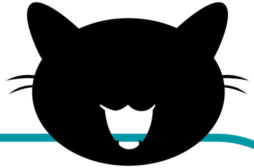
doi: 10.1016/j.jemermed.2018.09.007
doi: 0.1002/14651858.CD010344.pub2

Treatment patterns

doi: 10.1016/j.ajem.2019.12.012
doi: 10.1016/j.jemermed.2018.09.007

doi: 10.1177/1098612X221127234
doi: 10.1111/j.1534-6935.2003.00100.x

1-2 studies only



64%	**Insulin/Dextrose (alone or combi)**	36-80%
55%	**Ca-Gluconate**	76-80%
33%	**β2 agonists**	---
29%	**Bicarbonate**	17-28%
24%	**Dialysis**	---

Calcium Gluconate

Mechanism

1. Re-establishes RMP-TP relationship
2. ↑ conduction velocity

Duration

Onset: Immediate (< 1min)

Duration: 30-60 min

PMID: 16572868
doi: 10.1016/j.phrs.2016.09.039
doi: 10.1016/j.ekir.2017.10.001
doi:10.1097/CCM.0000000000006376

Calcium Gluconate

Dose

50-150 mg/kg slow (5-30 min w ECG)
(1-1.5ml/kg 10% Ca-Glu)

Redose: ECG changes persist

Comments

- Not necessary when ECG normal
- $CaCl_2$ has 3x Ca
- $CaCl_2$ hyperosmolar + more acidic
- Ca-glu can cause necrosis too

doi: 10.1097/CCM.0000000000006376

Insulin

+

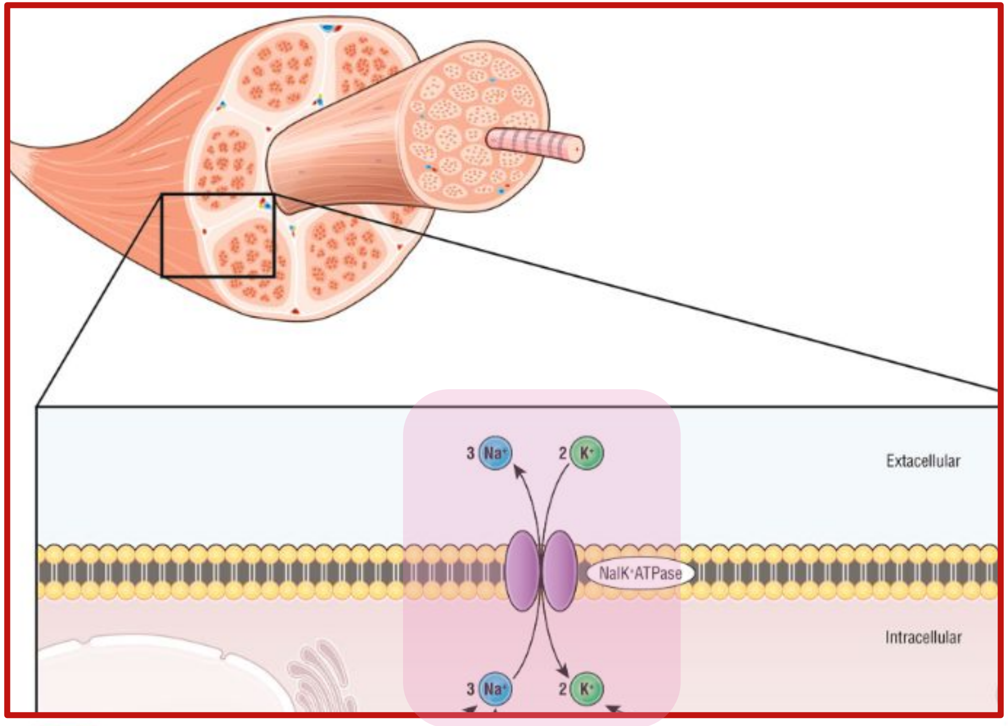
Dextrose

β2

agonists

Sodium

Bicarbonate



doi: 0.1186/s13613-019-0509-8

Insulin
+
Dextrose

Dose

Initial: 0.1-0.5 U/kg regular insulin

Dextrose: 1-2g/unit insulin

½ as bolus ½ as 1-2h CRI	Just bolus	Just add to IVFT

Usual bolus 2.5-5% dextrose IVFT	Humans: All of above. None if >200mg/dL

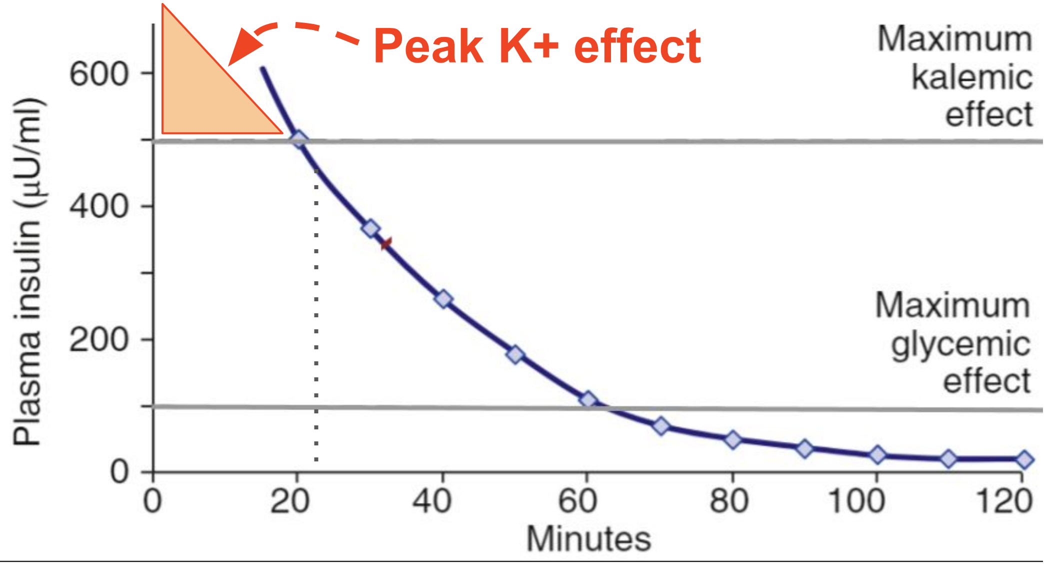
Redose: If K still >6.0-6.5

Insulin + Dextrose

Duration

Onset: Within 15 min, peak @ 20-60 min

Duration: 4-6 hours



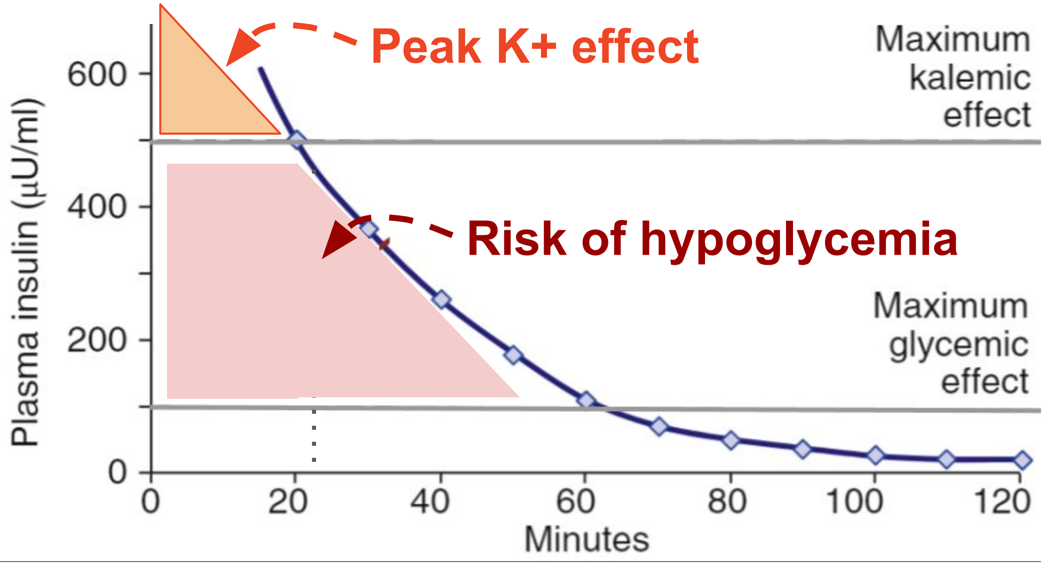
doi: 10.1016/j.kint.2015.11.018
doi: 10.1016/j.ekir.2017.10.001
doi: 10.1016/j.jemermed.2018.04.004

Insulin
+
Dextrose

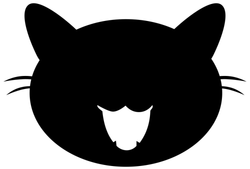
Comments

↑ evidence of risk of hypoglycemia even with dextrose supplementation

0.1-0.14 U/kg bolus



Risk of hypoglycemia

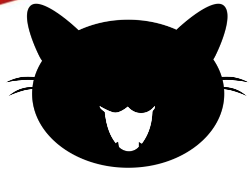


15-30%	**Incidence**	48%
2.5g-6g/unit	**Dextrose:Insulin**	**2g/unit** 0.4-100g/unit None protective

** Even early dextrose CRI**

doi: 10.1177/1098612X221127234
doi: 10.1186/s13613-019-0509-8
doi: 10.1038/s41598-020-79180-7

Risk of hypoglycemia



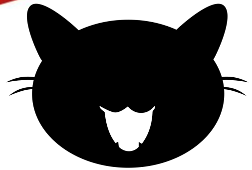
2.5g-6g/unit **Dextrose:Insulin** 2g/unit (0.4-100g/unit)

Key points:

- 2g/unit dextrose not enough
    - 5g/unit dextrose instead?
- Lower insulin dose (e.g 0.1 U/kg)

doi: 10.1177/1098612X221127234
doi: 10.1016/j.ajem.2019.158374
doi: 10.1016/j.ekir.2017.10.009

Risk of hypoglycemia



1-3h (peak 90min)	Onset time	Within 6-12h (5h)

Key points:

- Monitoring BG @ 30min
- Then q1-2h up to 12h, especially 1st 6h

β2 agonists

- Salbutamol
- Albuterol
- Terbutaline

Duration

Onset: Within 5 mins
(NB: terbutaline 20-40 min)

Duration: Nadir 60mins (90 ug)
Nadir 30mins (450 ug)
Sustained 2-6h in humans

doi: 10.1111/jvim.16552
*doi:*10.1016/j.ekir.2017.10.001
*doi:*10.1016/j.jemermed.2018.04.004

β2 agonists

Dose

- **Salbutamol or albuterol**
  - 90ug or 450ug per activation
- **Terbutaline**
  - 0.01mg/kg slow IV/IM/SQ

doi: 10.1111/jvim.16552
*doi:*10.1016/j.ekir.2017.10.001
*doi:*10.1016/j.jemermed.2018.04.004
Small Animal Emergency and Critical Care 3rd Ed

Rechecking K levels

Check BG too!

Break

Hypokalemia

General classification of hypokalemia

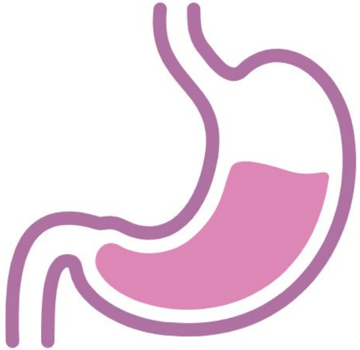
Mild
3.5-3 mEq/L

Moderate
3-2.5 mEq/L

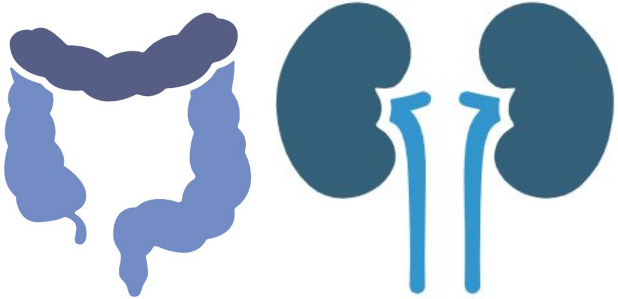
Severe
<2.5 mEq/L

doi: 10.1186/s13054-019-2679-z

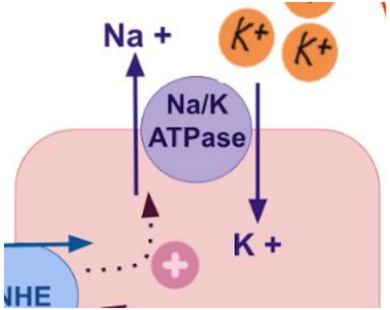
Common causes of hypokalemia



Lack of intake



Excessive losses



Intracellular shifting

Common causes of hyperkalemia

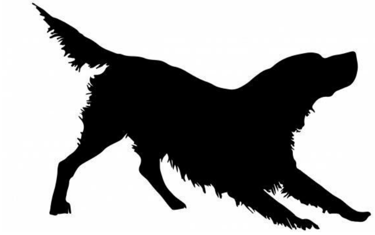
1 GI disease

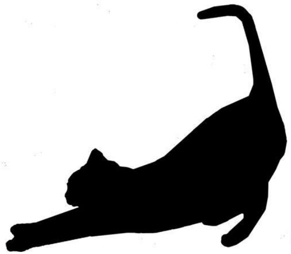
2 CVS (Frusemide?) | Urinary tract Endocrine

* Note: There many other causes*

doi: 10.1111/vec.12889

Common causes of hyperkalemia





1 GI disease

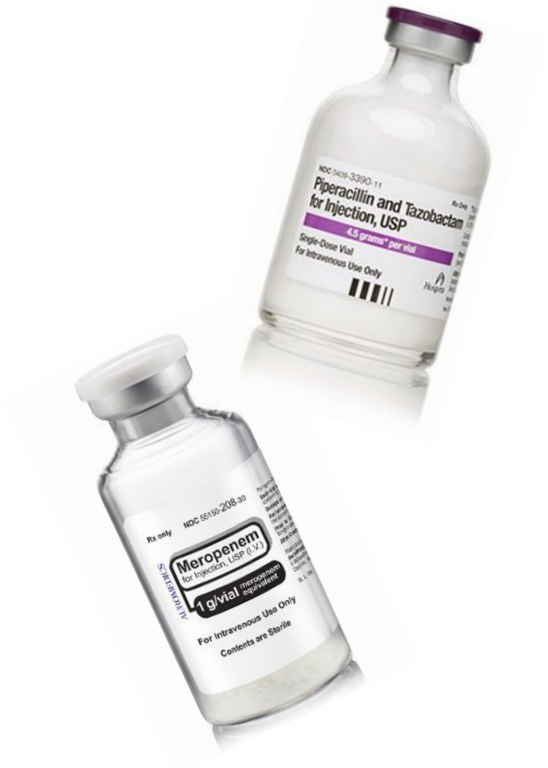
2 CVS (Frusemide?) | Urinary tract Endocrine

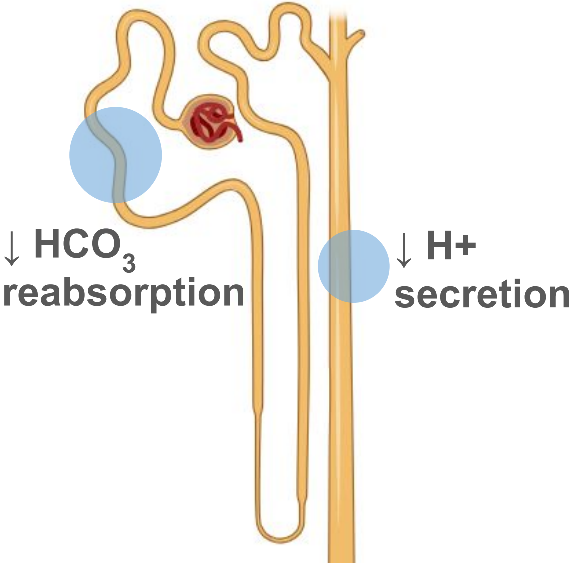
Risk factors

- ↓ intake
- Fluid therapy
- Hyperglycemia
- GI losses
- Renal disease

doi: 10.1111/vec.12889

Drugs and hypokalemia

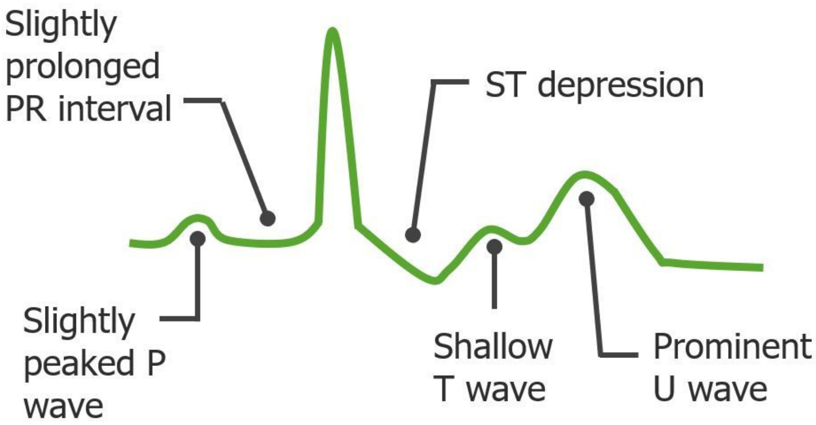




Renal Tubular Acidosis
(may be drug induced)

Hypokalemia and the heart

- Not as well documented
- ECG changes common too
  - 40% in humans



From lecturio.com

doi: 10.1111/joim.13757
doi: 10.1111/joim.13757
doi: 10.1016/j.jelectrocard.2019.09.005

Treating hypokalemia

- Concentrated KCL
- 0.4-1 mEq/kg/h
  - Max 10 mEq total
- Target 3.5-5.0 mEq/L

Medical Errors

HyperK

doi: 10.1177/0885066617752659
doi: 10.1007/s00246-012-0565-4
doi: 10.5144/0256-4947.2005.105

Treating hypokalemia

- Oral KCL
- Boluses only for severe hypoK
- Diluted KCL
  - ICU 400 mEq/L
  - Wards 40 mEq/L

doi: 10.1177/0885066617752659
doi: 10.1136/bmjoq-2019-000666
doi: 10.1136/bmjopen-2016-011179
doi: 10.1097/PCC.0000000000000849

Treating hypokalemia

May not be sufficient?

TABLE 56.1 Guidelines for Routine Intravenous Supplementation of Potassium in Dogs and Cats[27]

Serum Potassium Concentration (mEq/L)	mEq KCl to Add to 250 ml Fluid[a]	mEq KCl to Add to 1 L Fluid	Maximal Fluid Infusion Rate[b] (ml/kg/hr)
<2.0	20	80	6
2.1 to 2.5	15	60	8
2.6 to 3.0	10	40	12
3.1 to 3.5	7	28	18
3.6 to 5.0	5	20	25

Small Animal Critical Care Medicine 3rd Edition Chap 56

Treating hypokalemia

Mild
3.5-3 mEq/L
0.1-0.2 mEq/kg/hr

Moderate
3-2.5 mEq/L
0.2-0.3 mEq/kg/hr

Severe
<2.5 mEq/L
0.3-0.5 mEq/kg/hr

Note: This is presenter's preference

More helpful in hypokalemic with on-going cause for hypoK (e.g DKA, diuresis)

Is there a limit?

Critical hypokalemia

(resp paralysis, bad arrhythmias)

- > 0.5 mEq/kg/hr
- Up to 2 mEq/kg/hr
- ICU + ECG monitoring

Severe
<2.5 mEq/L
0.3-0.5 mEq/kg/hr

doi: 10.1111/vec.12416
doi: 10.1177/0885066617752659
doi: 10.1007/s00246-012-0565-4
doi:10.5144/0256-4947.2005.105

Back calculation

Harry 2.5kg: Refeeding syndrome

Plasma K 2.7 mEq/L
0.2mEq/kg/h in LRS 6 ml/hr

Moderate
3-2.5 mEq/L
0.2-0.3 mEq/kg/hr

0.2 mEq/kg/h x 2.5kg= 0.5 mEq/h

0.5 mEq/h in LRS 6 ml/h=0.5 mEq/6ml

0.08 mEq/ml= 83 mEq/L

Practical consideration

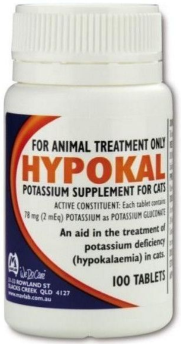
Poorly mixed fluid bags

- 72%: within 5 mEq/L
- **15%: +5 to +20 mEq/L**
- **12%: +20 to >280 mEq/L**

doi: 0.1111/jvim.12588

Mix well!! Squeeze injection ports + invert 4x

Oral potassium



Starting dose 2 mEq per 4.5kg q12h
(up to q4-8h as required)

- Eating well or feeding tube
- Unable to tolerate IV volume (e.g. CHF)
- KCL in bag close to 180-200 mEq/L (osmolality issue)
- > 0.5 mEq/kg/hr

doi: 10.1111/vec.12561

Back calculation

Moderate
3-2.5 mEq/L
0.2-0.3 mEq/kg/hr

Harry 2.5kg: Refeeding syndrome

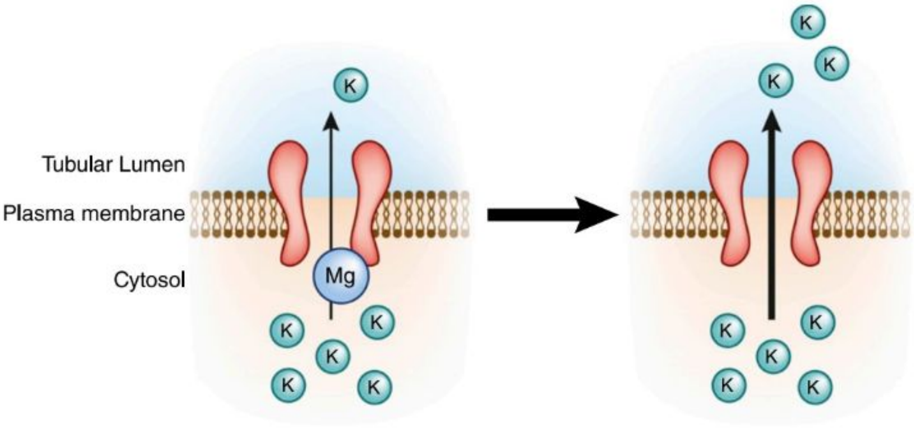
Plasma K 2.7 mEq/L
0.2mEq/kg/h in LRS 6 ml/hr

KCL 83 mEq/L

Osmolality: 274 + (83 x 2)= 440 mOsm/L

*** Peripheral veins 600-700 mOsm/L***

Magnesium to the rescue!



- 0.25 to 1 mEq/kg/24h as CRI
- NaCl 0.9% or D5W
- Plasmalyte has Mg, but not sufficient

↓ Mg permits K loss in urine

doi: 10.2215/CJN.05920613

Small Animal Critical Care Medicine 3rd Edition Chap 58

Treatment target

Normal 3.5-5.0 mEq/L

Association between potassium concentrations, variability and supplementation, and in-hospital mortality in ICU patients: a retrospective analysis

Lowest mortality in patients with 3.5-4.5 mEq/L

JAMA | Original Investigation

Potassium Supplementation and Prevention of Atrial Fibrillation After Cardiac Surgery

The TIGHT K Randomized Clinical Trial

No difference in development arrhythmia when supplemented at < 3.6 mEq/L

doi: 10.1186/s13613-019-0573-0
doi: 10.1001/jama.2024.17888

Treatment target

Normal 3.5-5.0 mEq/L

Association between potassium concentrations, variability and supplementation, and in-hospital mortality in ICU patients: a retrospective analysis

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Potassium Supplementation and Prevention of Atrial Fibrillation After Cardiac Surgery

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Ok target 3.5-4.5 mEq/L

doi: 10.1186/s13613-019-0573-0
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Highlights

- Dyskalemias cause arrhythmias
- Insulin 0.1 IU/kg enough in hyperK
- Small drop in blood K= large deficit
- Consider rate based hypoK correction
- Target 3.5- 4.5 mEq/L

VetUpdates

STAY IN THE LOOP


Journal Of Veterinary Emergency And Critical Care

- Assessment of change in end-tidal CO2 after fluid challenge as a marker of fluid responsiveness as measured by the aortic velocity time integral in healthy anesthetized mechanically ventilated dogs.

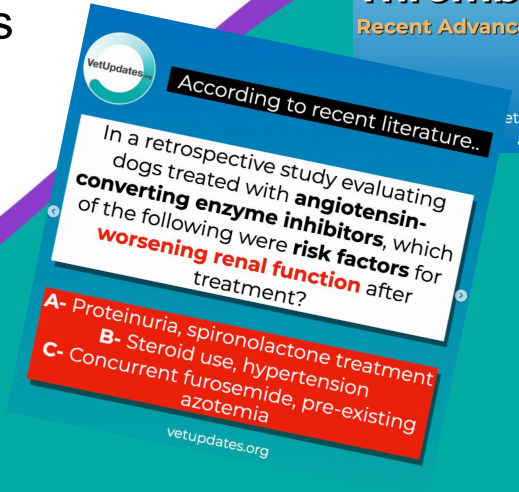
Tarragona L, Donati PA, ... Otero PE - J Vet Emerg Crit Care (San Antonio) - (Epub 2024 Dec 5)

Frontiers In Veterinary Science

- Utilization of peripheral glucose and lactate differences in the diag thromboembolism: a multi-center study.

Yee M, Guillaumin J, ... Walton R - Front Vet Sci - 2024 Dec 4 - Open access

- Monthly lit newsletters
- Guidelines/Reviews
- Lit quizzes
- And more!



Questions?