Hypokalemia

July 4, 2024 by **Josh Farkas**

CONTENTS

rapid reference

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consider risk factors for arrhythmia 📖 (#risk_stratification)

- ECG changes (especially QT prolongation).
- Digoxin.
- Myocardial ischemia.
- Medications that prolong QT interval and promote torsade de pointes.
- Concomitant severe hypomagnesemia.
- Severe hypokalemia (<2.5 mM).
- Ongoing *fall* in potassium likely (e.g., DKA or refeeding syndrome).

evaluation 📖 (#workup)

- Repeat electrolytes if doubt exists about their validity (e.g., inconsistent with clinical context & ECG).
- Check magnesium level if not known.

consider magnesium repletion 📖 (#magnesium_repletion)

- IV magnesium may be the fastest way to reduce the risk of arrhythmia (because magnesium can be given *rapidly*).
- Repletion of magnesium is often necessary to successfully replete the potassium.

consider target potassium level 📖 (#target_potassium_level?)

- Nearly all patients: >3.5 mM.
- DKA with adequate renal function: >5 mM.

enteral route is usually preferred 📖 (#enteral_route_generally_preferred)

- **Contraindications to enteral route**:
  - NPO or unable to take PO.
  - Profound shock with questionable absorption.
  - Not preferred for severe hypokalemia (<2.5 mM).
- Selection of agent:
  - *Potassium chloride* is generally utilized.
  - *Potassium citrate* may be useful for patients with metabolic acidosis.

intravenous potassium 📖 (#intravenous_potassium)

- Selection of agent:

    - *Potassium chloride* is generally utilized.
    - *Potassium acetate* may be useful for patients with metabolic acidosis.
- Typical rates:
    - Rate of 10 mEq/hr for routine repletion.
    - Rate of 20 mEq/hr for severe hypokalemia or DKA (either via a central line, or split into two simultaneous infusions of 10 mEq/hr in two peripheral lines).

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diagnosis

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causes of spuriously low lab values (pseudo-hypokalemia)

- [1] Delayed sample analysis (cells absorb potassium while the blood tube is sitting around).
- [2] Markedly elevated cell counts, usually acute leukemia with WBC >100,000/uL (leukocytes take up potassium while the blood is awaiting analysis).
- [3] Recent administration of IV insulin. (Schmidt 2022)
- 💡 Unlike pseudohyperkalemia, pseudohypokalemia is *uncommon*. (33974032 (https://pubmed.ncbi.nlm.nih.gov/33755054/) Login to Jenni)

ECG changes & arrhythmias related to hypokalemia

- Discussed further here: 📖 (https://emcrit.org/ibcc/hypok/#hypokalemia)

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interpretation of low potassium levels & risk stratification

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rough correlation with symptoms:

- 3.5-5 mM = Normal.
- 3-3.5 mM = Mild hypokalemia.
    - Asymptomatic.
- 2.5-3 mM = Moderate hypokalemia.
    - May cause mild symptoms (e.g., ileus, constipation).
- <2.5 mM = Severe hypokalemia.
    - Muscle cramps.
    - Weakness (often *ascending*).

    - Torsade de pointes may occur, especially if additional risk factors:
        - Hypomagnesemia.
        - Digoxin.
        - MI.
        - QT-prolonging medications.
    - Heart failure.
    - Rhabdomyolysis.
- **<2 mM = Super severe hypokalemia**
    - Weakness involving the diaphragm.

risk factors for complications from hypokalemia

- ⚠️ Severe hypokalemia (potassium <2.5 mM).
- ⚠️ Clinical context where potassium is likely to fall further (e.g. DKA or refeeding syndrome)
- ⚠️ ECG changes due to hypokalemia (e.g., QT prolongation).
- ⚠️ Increased risk of arrhythmia:
    - Patients on digoxin.
    - Myocardial ischemia or scarring.
    - Concomitant deficiency of magnesium.
    - Medications that prolong QT interval and promote torsade de pointes.

hypokalemia is generally well tolerated

- In the absence of the above factors, hypokalemia is well tolerated (and can be treated gradually). Hypokalemia is generally less dangerous than hyperkalemia.
- 💡 For patients with a combination of hypokalemia plus hypomagnesemia, hypomagnesemia should be corrected aggressively (which is safe), but hypokalemia must be corrected in a more controlled fashion. This strategy may quickly decrease the risk of arrhythmia.

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causes

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[1/4] potassium shifts into the cells

- Insulin (e.g., DKA resuscitation).
- Refeeding syndrome.
- Beta-agonists:
    - Albuterol, terbutaline.

    - Epinephrine (including endogenous epinephrine surges from stress).
- Hypothermia (this may involve both a shift of potassium into cells as well as renal potassium losses due to cold-induced diuresis). (Irwin 2023)
- Alkalemia (direct effect is relatively small) (Irwin 2023)
- Theophylline/caffeine toxicity. (Koyner 2021)
- Hypokalemic periodic paralysis. (31227226 (https://www.ncbi.nlm.nih.gov/pubmed/31227226))
    - Two forms:
        - [1] Familial form with onset <20 years old.
        - [2] Acquired form associated with hyperthyroidism, typically in Asian and Mexican men.
    - Episodes may be precipitated by exercise, stress, or carbohydrate intake – likely related to release of epinephrine or insulin. (Schmidt 2022; Irwin 2023)
    - Treatment is challenging because there is a risk of rebound hyperkalemia (so potassium administration should be *cautious*). Oral administration of 60-120 mEq of KCl usually aborts acute attacks. (Irwin 2023)
- Increased bone marrow activity:
    - Treatment with GM-CSF.
    - Treatment of B12 or folate deficiency.

[2/4] extra-renal potassium loss

- GI:
    - Vomiting or large-volume gastric suction.
    - Fistulas.
    - Bowel resection/ostomy.
    - Diarrhea.
- Profound sweating.

[3/4] reduced potassium intake (rarely the sole cause)

- Anorexia nervosa.
- Alcoholism. (Total body potassium depletion is multifactorial, including inadequate intake, emesis, and alcoholic ketoacidosis. Following hospital admission, refeeding may exacerbate hypokalemia.) (Schmidt 2022)

[4/4] renal potassium loss

- Hypomagnesemia (hypomagnesemia promotes hypokalemia, but these usually coexist because underlying disease processes cause both hypokalemia and hypomagnesemia).
- High-dose penicillins (distal delivery of nonreabsorbable anions).

- Sodium-wasting nephropathy (e.g., post-ATN or post-obstructive).
- **Associated with metabolic alkalosis**:
    - Mineralocorticoid excess:
        - Elevated renin & aldosterone:
            - Renal artery stenosis.
            - Renin secreting tumor.
            - Malignant hypertension (regardless of the underlying cause, this is a high-renin, high-aldosterone state). (Irwin 2023)
        - Low renin & elevated aldosterone:
            - Primary hyperaldosteronism (due to an adenoma or bilateral adrenal hyperplasia).
            - Glucocorticoid suppressible hyperaldosteronism.
        - Low renin & low aldosterone:
            - Cushing syndrome.
            - Exogenous steroid.
            - Licorice ingestion.
    - Vomiting (potassium loss isn't due to emesis itself, but rather due to increased renal potassium excretion due to increased distal delivery of bicarbonate and hyperaldosteronism as a response to hypovolemia).
    - Diuretic use.
- **Associated with metabolic acidosis**:
    - Diabetic ketoacidosis.
    - RTA-1, RTA-2 (see below etiologies):

RTA-1 (Generalized distal, acidification failure)	RTA-2 (Proximal)	RTA-4 (Aldosterone resistance or deficiency)
Lab abnormalities		
Bicarb ~10-20 mM	Bicarb ~12-20 mM	Bicarb ~18-22 mM
K ↓↓	**K** ↓	**K** ↑ (~5.5-6.5)
	Usually: ↓ Ca, ↓ Mg, ↓ Phos, ↓ urate	
No glucosuria	Glucosuria Proteinuria may occur	No glucosuria
pH >5.3	pH usually <5.5 will incr s/p bicarb load	pH<5.5 aldo deficient pH>5.5 voltage defect
Urine OG <150 mOsm	Urine OG >150 mOsm	Urine OG <150 mOsm
Causes		
Medications Amphotericin NSAIDs Lithium Ifosfamide Foscarnet **Genetic disorders** Wilson's disease Sickle cell anemia Ehlers-Danlos, Marfan's **Metabolic disorders** Hypercalciuria Hyperthyroidism Hyperparathyroidism Vitamin D intoxication **Other** SLE, RA, Sjogren Thyroiditis Primary Biliary Cirrhosis Cryoglobulinemia Multiple myeloma. Amyloidosis. HIV-assoc nephropathy Obstructive nephropathy Post-transplant rejection Amyloidosis. Toluene abuse.	**Medications** Carbonic anhydrase inhibitors - Acetazolamide - Topiramate - Mafenide acetate Generalized defect - Aminoglycosides - Cyclosporine, tacrolimus - Tenofovir, anti-retrovirals - Valproic acid - Chemotherapeutics (platinum, Ifosfamide) **Genetic disorders** Wilson's disease **Metabolic disorders** Hypocalcemia Hyperparathyroidism Vitamin D deficiency **Other** Multiple myeloma, monoclonal gammopathy, amyloidosis, light chain deposition disease. Nephrotic syndrome. SLE, Sjogren Renal transplant rejection Lead/Cadmium/Mercury Paroxysmal nocturnal hemoglobinuria	**Medications** Trimethoprim, pentamidine Amiloride, triamterene Spironolactone, eplerenone ACE-i, ARB, renin inhibitors NSAIDs, beta-blockers Cyclosporine, tacrolimus Heparin **Genetic disorders** Sickle cell anemia **Metabolic disorders** Adrenal insufficiency **Other** Diabetic nephropathy Hypertensive nephropathy Multiple myeloma Monoclonal gammopathy SLE Renal transplant rejection Amyloidosis Obstructive nephropathy Sickle cell disease HIV -The Internet Book of Critical Care

workup

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If hypokalemia is severe or persistent, then a full evaluation may be useful. Most patients with hypokalemia don't require in in-depth workup.

[1] check full electrolytes (including Ca/Mg/Phos)

- Check a full electrolyte panel including Ca/Mg/Phos. Electrolyte abnormalities often occur in pairs and triplets ("electrolytic disarray").
- **Magnesium level** is the most important contributing factor, for several reasons:
  - [a] Hypomagnesemia is common (most patients with hypokalemia have hypomagnesemia as well). (29540487 (https://www.ncbi.nlm.nih.gov/pubmed/29540487))
  - [b] Treatment of hypomagnesemia may be required to effectively treat hypokalemia.
  - [c] Expedient treatment of hypomagnesemia may reduce the risk of Torsade de pointes.

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[2] review the medication list, focusing on:

- Diuretics.
- Insulin.
- Beta-agonists.
- Steroid.
- Antibiotics:
  - Penicillins, including piperacillin.
  - Amphotericin.
  - Aminoglycosides.
  - Tenofovir, antiretrovirals.
  - Foscarnet.
- Chemotherapeutics:
  - Platinum agents.
  - Ifosfamide.
- Miscellaneous:
  - Mafenide acetate.
  - NSAIDs.
  - Lithium.
  - Topiramate.
  - Valproic acid.

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[3] review recent history for clues, e.g.:

- Vomiting or gastric suction.

- High-output fistula.
- Diarrhea.
- Polyuria.
- Profound sweating.
- Malnutrition followed by refeeding syndrome.
- Alcoholism.
- Hypothermia.
- Substantial hypertension.
- Recent ATN (acute tubular necrosis) or obstructive renal failure.

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[4] general schema for approaching the etiology of hypokalemia

- [a] Consider extrarenal potassium loss or trans-cellular shifts:
  - Extrarenal loss is often suggested by history (e.g., diarrhea, vomiting, sweating).
  - Transcellular shifts may be suggested by context (e.g., beta-agonist use, insulin) and fluctuations in potassium level.
  - Urine potassium levels may be utilized to evaluate this more fully (discussed in the next section).
- [b] Is there a metabolic alkalosis?
  - Is the patient hypertensive –> Consider hyperaldosteronism of some form.
  - Vomiting.
  - Diuretic use.
- [c] Is there a metabolic acidosis?
  - Diabetic ketoacidosis.
  - RTA type-1 or 2.
  - Sodium-wasting nephropathy may present similarly (e.g., post-ATN or post-obstructive).

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sophisticated laboratory tests

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FEK (fractional excretion of potassium)

- Begin by checking urine potassium, creatinine, sodium, and chloride.
- FEK helps sort out renal versus non-renal potassium loss.
- FEK may be calculated based on spot urine potassium and creatinine levels (using a calculator found here (https://globalrph.com/medcalcs/fractional-excretion-of-potassium/)).

- A fractional excretion of potassium >9.3% suggests renal potassium wasting (with sensitivity of 81% and specificity of 86%). (33096028 (https://pubmed.ncbi.nlm.nih.gov/33096028/) Login to Jenni) In reality, values close to the cutoff of 9.3% are ambiguous, with values further away being more definitive.

spot potassium/Creatinine ratio

- K/Cr ratio <13 mEq/mg Cr (or <2.5 mEq/mM Cr) is a normal response to hypokalemia. (Koyner 2021) Higher values suggest urinary potassium wasting.
- It's unclear precisely how this compares to the fractional excretion of potassium, but they should yield consistent results.

spot urine potassium concentration

- It may be used if the urine creatinine level isn't known.
- Urine potassium >>15-19 mM indicates renal potassium wasting.

aldosterone/renin ratio

- An elevated aldosterone/renin ratio suggests hyperaldosteronism (>750 pmol/L per ng/ml/h, or 27 ng/dL per ng/mL/h). (33755054 (https://pubmed.ncbi.nlm.nih.gov/33755054/))
- Aldosterone and renin levels should ideally be measured after correction of potassium, because otherwise hypokalemia may suppress the aldosterone level. (33755054 (https://pubmed.ncbi.nlm.nih.gov/33755054/))

(The transtubular potassium gradient (TTKG) is no longer recommended.) (33755054 (https://pubmed.ncbi.nlm.nih.gov/33755054/))

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target potassium level?

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generally target a normal potassium level (>3.5 mM)

- Targeting a potassium level >3.5 mM seems optimal for most patients.
- Cardiac patients:
  - Traditionally, the target has been >4 mM in efforts to reduce the risk of arrhythmia.
  - Larger, modern studies have shown that the safest potassium range in patients with myocardial infarction may be 3.5-4.5 mM. (22235086 (https://www.ncbi.nlm.nih.gov/pubmed/22235086) , 26714972

(https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5410890/) , 24560065 (https://www.ncbi.nlm.nih.gov/pubmed/24560065)) Either higher or lower potassium values correlate with worse outcomes (figure below). This is admittedly correlative data, but it's the best data that we have.

  - An evidence-based potassium target for cardiac patients would therefore seem to be >3.5 mM.
- Critically ill patients: retrospective data involving ICU patients also supports targeting a potassium >3.5 mM. (25560457 (https://pubmed.ncbi.nlm.nih.gov/25560457/) Login to Jenni)

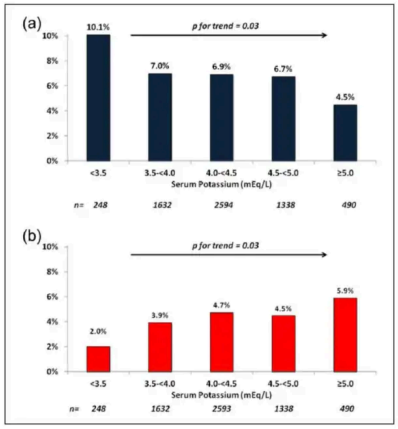

Figure 2. (a) Incidence of ventricular tachycardia (⩾8 beats) and (b) ventricular pauses ⩾3 s based on potassium levels.

MERLIN-TIMI 36 correlated potassium levels with outcome among 6515 patients with acute coronary syndrome. Patients with potassium of 3.5-4 mM had similar (or perhaps *lower*) risks of ventricular tachycardia or ventricular pauses, compared to patients with potassium level >4 mM (Figure 2 👆). Cardiovascular death was *lowest* among patients with a potassium level of 3.5-4 mM (Figure 4 👉). This data argues against the traditional practice of targeting potassium levels >4 mM in patients with myocardial infarction (Patel RB et al. 2017, PMID 26714972).

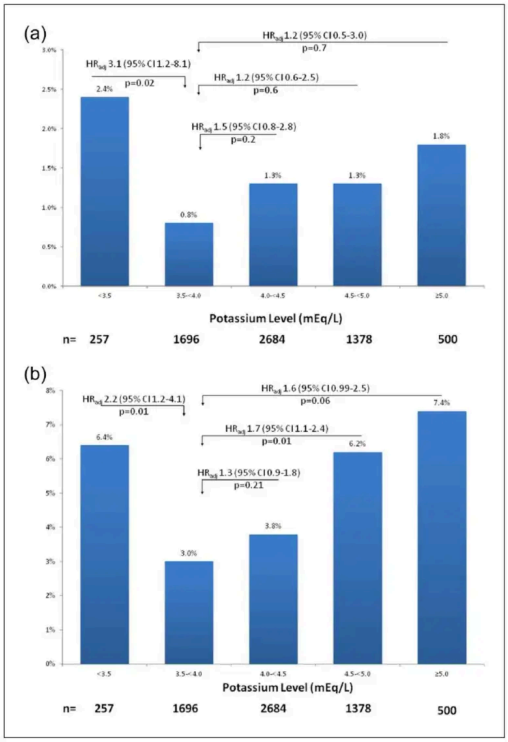

Figure 4. (a) Cardiovascular death at 14 days and (b) one-year based on potassium levels.

diabetic ketoacidosis: target >5 mM

- Patients being resuscitated from DKA will generally tend to drop their potassium levels over time.
- In the absence of renal dysfunction, targeting a high-normal potassium level is often useful.

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enteral potassium

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contraindications, drug interactions, side effects 👎

contraindications

- Inability to take PO and/or absence of an enteral feeding tube.

side effects

- Hyperkalemia.
- Metabolic alkalosis (potassium acetate).
- NAGMA (potassium chloride).
- Dyspepsia.

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indications, advantages 👍

reasons that enteral potassium is preferred

- (1) Cheaper and generally easier.
- (2) It doesn't irritate veins.
- (3) Safer (oral potassium is more idiot-proof than IV potassium).

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dosing & formulations

formulations of oral potassium

- **Potassium chloride (KCl)**
  - KCl is the most commonly used formulation.
  - KCl is an *acidifying* medication (analogous to normal saline, it causes a non-anion-gap metabolic acidosis). This is especially useful in patients with metabolic *alkalosis*.
  - Slow-release microencapsulated (wax-matrix) KCl formulations are suboptimal if an immediate effect is desired. However, they may be better tolerated with less emesis. (31227226 (https://www.ncbi.nlm.nih.gov/pubmed/31227226))
- **Potassium citrate**
  - Potassium citrate is equally effective as KCl for the repletion of potassium. (6699979 (https://pubmed.ncbi.nlm.nih.gov/6699979/) Login to Jenni , 1988724 (https://pubmed.ncbi.nlm.nih.gov/1988724/))
  - Potassium citrate is useful in patients with NAGMA (non-anion-gap metabolic acidosis). The citrate will be converted into bicarbonate, thereby *improving* the acidosis.
  - Commonly available in the form of potassium citrate-citric acid* (https://reference.medscape.com/drug/cytra-k-potassium-citrate-citric-acid-999836) (e.g., POLYCITRA-K), which contains 2 mEq of potassium per ml.

maximal safe single dose?

- High doses of enteral potassium could theoretically increase the likelihood of gastric irritation.
- There doesn't appear to be any high-quality evidence regarding this.
- Limiting single doses of enteral potassium to ≲60 mEq might be a reasonable practice in most circumstances (using repeated doses rather than large single doses).

dose & schedule

- This involves clinical judgment based on the consideration of three factors:
  - [1] Total body potassium deficit (discussed further below ⚡ (#physiology:_potassium_pharmacokinetics)).
  - [2] Renal function.
  - [3] Expected intracellular *shifts* in potassium (e.g., in the context of DKA resuscitation).
- If the renal function is adequate and stable (e.g., GFR is >30 ml/min and the patient is not oliguric), then it's unlikely that oral potassium will cause hyperkalemia. In this scenario, oral doses of potassium may be scheduled and the potassium level can be checked intermittently.
  - For example: In a patient with normal renal function and a potassium level of 3 mM (estimated deficiency of ~100-200 mEq), a dose of 40 mEq KCl could be given q8hr with daily measurement of electrolytes.
- For patients with oliguria or renal insufficiency, closer monitoring is required to avoid overshoot hyperkalemia.

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intravenous potassium

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contraindications, drug interactions, side effects 👎

contraindications

- Mild-moderate hypokalemia with the ability to tolerate enteral potassium (as discussed above, an enteral route is generally preferred).

side effects

- Infusion site discomfort and thrombophlebitis.
- Hyperkalemia.
- NAGMA (potassium chloride).

- Metabolic alkalosis (potassium citrate).

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indications, advantages 👍

indications for IV potassium

- Inability to utilize enteral potassium (e.g., due to nausea/vomiting, or inability to tolerate enteral intake).
- Severe hypokalemia in need of emergent treatment (see “risk stratification” above).
- Profound shock plus severe hypokalemia (it is often unclear whether potassium would be adequately absorbed from the gut).

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dosing & formulation

selection of IV potassium formulation

- *Potassium chloride* is generally utilized.
- *Potassium acetate* may be useful for patients with metabolic acidosis (acetate is metabolized into bicarbonate).

typical rates of IV potassium administration

- 10 mEq/hour: Commonly used rate for routine potassium repletion.
- 20 mEq/hr:
    - Commonly used for severe hypokalemia or DKA.
    - Ideally, this shouldn't be run through a single peripheral IV line (to prevent vein sclerosis). This can be run either through a central line, or split into two 10 mEq/hr infusions through two *different* peripheral lines.
- The frequency of monitoring electrolytes depends on clinical acuity and renal function (similar to the monitoring of oral repletion above).

high-dose IV potassium administration

- Using high-dose IV potassium is rarely necessary. However, this *might* be preferable to the combination of simultaneously given intravenous and enteral potassium (which can lead to erratic pharmacology in critically ill patients, if the enteral potassium is absorbed in a delayed fashion).
- Possible regimens are listed below (*none* of which are supported by high-level evidence). A useful concept is that potassium levels should be repeated after every ~60 mEq of potassium

administered. (22901631 (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4776048/)) If potassium is given more *rapidly*, then it must be monitored more *frequently*.

- (1) Cardiac arrest due to hypokalemia (e.g. VT, VF, or asystole)
  - Start with 20 mEq potassium IV over 2-3 minutes. (16600469 (https://www.ncbi.nlm.nih.gov/pubmed/16600469))
- (2) Recurrent malignant arrhythmias with a pulse
  - Start with 20 mEq potassium IV over 10-20 minutes (infusion rate of 60-120 mEq/hr). (16600469 (https://www.ncbi.nlm.nih.gov/pubmed/16600469))
  - Down-titrate the rate rapidly as the ECG improves and the patient stabilizes.
- (3) Severe hypokalemia plus DKA
  - Hypokalemia *itself* isn't immediately life-threatening here, but hypokalemia impedes the ability to provide *insulin. (*Insulin generally shouldn't be started until the potassium is >3.3 mM.)
  - Infusion of potassium at a rate of 40-60 mEq/hr may be reasonable, depending on illness severity.
  - *Check potassium level very frequently* (e.g., every hour) with a point-of-care monitor to allow for *real-time titration of potassium at the bedside*. Don't give more than ~60 mEq potassium without repeating the level.

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magnesium repletion

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There are two general reasons to give magnesium:

[1] magnesium administration facilitates potassium retention

- Magnesium depletion is very common in patients with hypokalemia.
- Failure to treat the magnesium deficiency will make it difficult or impossible to fix the hypokalemia (hypomagnesemia causes renal potassium-wasting, so the patient will continue spilling potassium until their magnesium level is repleted).
- An RCT demonstrated that potassium retention was superior among patients maintained with a Mg concentration of ~2.8-3 mg/dL as compared to 2 mg/dL. Even if the serum magnesium level is within a low-normal range, IV magnesium supplementation may enhance the response to potassium supplementation (perhaps by treating an occult intracellular magnesium deficiency). (8565536 (https://pubmed.ncbi.nlm.nih.gov/8565536/))

[2] magnesium administration may rapidly reduce the risk of torsades de pointes

- It's not uncommon for patients to present with severe hypokalemia and also hypomagnesemia. The *combination* of these abnormalities *synergistically* increases the risk of torsade de pointes.
- Hypokalemia must be corrected in a controlled fashion, so this often takes several hours.
- Magnesium can be repleted rapidly (much faster than potassium). Aggressive magnesium administration may be the *fastest* approach to decrease the patient's risk of arrhythmia.
- (Hypomagnesemia is discussed further in this chapter (https://emcrit.org/ibcc/hypomagnesemia/#top) .)

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other measures

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gastric losses

- For patients with ongoing gastric fluid loss, initiation of a proton pump inhibitor may minimize electrolyte derangements being caused by this. (The main driver of hypokalemia due to gastric fluid loss is the metabolic alkalosis, so avoiding loss of gastric acid will prevent this.)

potassium-sparing diuretics

- These may be useful in the following situations:
  - [1] Patients with severe volume overload who require *ongoing* diuresis.
  - [2] Patients with persistent renal potassium wasting, with inadequate response to potassium supplementation alone. (32138884 (https://pubmed.ncbi.nlm.nih.gov/32138884/) Login to Jenni)
- Options:
  - Amiloride (https://emcrit.org/ibcc/diurese/#amiloride) has the advantage of working more rapidly, making it the most attractive option in the ICU.
  - Spironolactone (https://emcrit.org/ibcc/diurese/#spironolactone) may be considered, but it only becomes effective after ~1-2 days.

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physiology: potassium pharmacokinetics

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the potassium deficit is often large

- Patients with hypokalemia often have a large *total-body potassium deficit*. This varies depending on acid/base status, but to get a general idea: (31227226 (https://www.ncbi.nlm.nih.gov/pubmed/31227226))
  - K of 3 mEq/L may correlate with a potassium deficit of 100-200 mEq.
  - K of 2 mEq/L may correlate with a potassium deficit of 400-600 mEq.
- The relationship between potassium level and total-body potassium deficit is *exponential* (figure below). As the potassium level falls progressively lower, this represents an exponentially large increase in the total body potassium deficit.

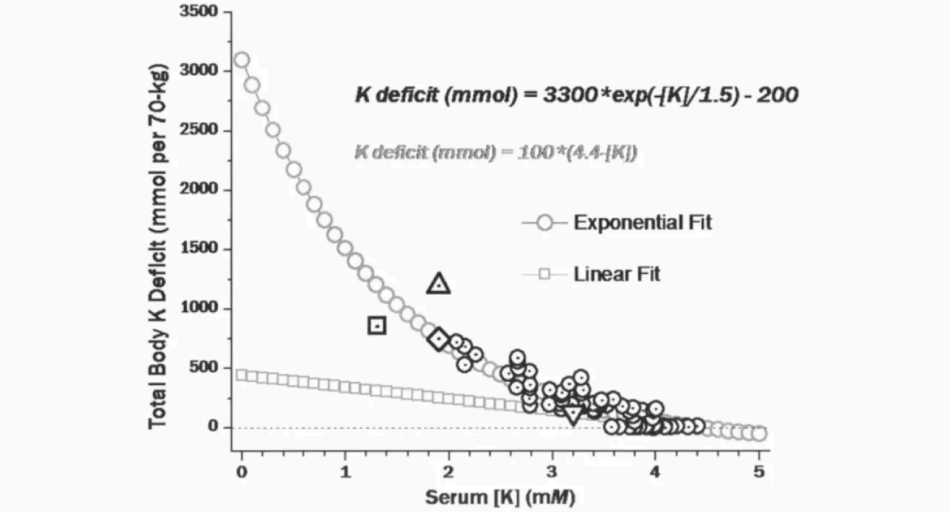

Fig. 3.5 Relationship of serum [K^+] and estimated total body K^+ deficit. The total body K^+ deficit has traditionally been estimated using a linear equation, as shown by the *squares*, for example. The exponential equation (*circles*) was derived by fitting data (*dotted circles*) obtained by Sterns et al. [166]. The estimated total body K^+ deficit (per 70-kg) in mmol is given by $3{,}300 \times exp(-[K^+]/1.5) - 200$, where [$K^+$] is in mM. Other patients from the literature are also plotted, including the mean deficit from patients reported by Kassirer and Schwartz (*dotted inverted triangle*) [71], Murthy et al. (*dotted triangle*) [168], Murakami et al. (*dotted diamond*) [167], and Yasue et al. (*dotted square*) [169]

Segal equation for potassium deficit: Although often approximated as a *linear* function, the potassium deficit is better estimated as an *exponential* function.

-Segal A, Potassium and the Dyskalemias, in Core *Concepts in the Disorders of Fluid, Electrolytes and Acid-Base Balance*, Editors Mount DB, Sayegh MH, Singh AK, New York (Springer 2013) Pages 49-102 (https://bit.ly/33eoxGe)

estimating the potassium deficit in clinical context

- This depends on two factors:
  - The serum potassium level.
  - The presence of any factors which may cause shifting of potassium in or out of the cells.
- For example, diabetic ketoacidosis causes potassium to shift out of the cells. Therefore, the potassium deficit may be even *larger* than would be estimated based on the above formula.

most of the deficit occurs *intracellularly*

- The vast majority of potassium in the body is located intracellularly. Thus, most of the total body potassium deficit represents deficient *intracellular* potassium.
- The intracellular nature of the potassium deficit means that IV potassium must be administered *slowly*.
  - Time is required for potassium to enter the cells.

- Rapid administration may cause serum levels to be elevated (even though there is a total-body potassium deficit!). Serum hyperkalemia is dangerous. Furthermore, serum hyperkalemia may cause poor retention of potassium (as it will tend to encourage potassium excretion in the urine).

- Bedside clinical implications:
  - (1) IV potassium should never be given as a bolus.
  - (2) Even in severely hypokalemic patients, aggressive IV potassium administration can be dangerous (more on this below).

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podcast

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(https://i0.wp.com/emcrit.org/wp-content/uploads/2016/11/apps.40518.14127333176902609.7be7b901-15fe-4c27-863c-7c0dbfc26c5c.5c278f58-912b-4af9-88f8-a65fff2da477.jpg)

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questions & discussion

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To keep this page small and fast, questions & discussion about this post can be found on another page ***here*** (https://emcrit.org/pulmcrit/hypokalemia-2/) .

- Failure to check and replete magnesium levels.
- Excessive use of intravenous potassium repletion, when enteral potassium would be a safer and easier strategy.
- Aggressive repletion of mild hypokalemia in patients with renal failure (hyperkalemia is generally *much more dangerous* than hypokalemia, so better to err on the low side).

Guide to emoji hyperlinks 🔗

- 🧮 = Link to online calculator.
- 💊 = Link to Medscape monograph about a drug.
- 💉 = Link to IBCC section about a drug.
- 📖 = Link to IBCC section covering that topic.
- 🌊 = Link to FOAMed site with related information.
- 🎥 = Link to supplemental media.

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The Internet Book of Critical Care is an online textbook written by Josh Farkas (@PulmCrit), an associate professor of Pulmonary and Critical Care Medicine at the University of Vermont.