Electrolyte Replacement: A Review

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Abstract

In accordance with a best practice model for the delivery of care to ICU Patients, a process of developing protocols for the standard replacement of fluid & electrolytes should exist in most units. This is an important step in an evolution towards a systems-based approach in the ICU. As a baseline for these changes, we must alter the way in which we monitor lab values.

INTRODUCTION

We recommend checking "routine labs" on a 4am-4pm cycle (every 12 hours) on ALL stable ICU patients. Other phlebotomy draws should only be performed when clinically indicated; we must become more efficient with our use and interpretation of laboratory values. Depending on the underlying abnormality, aggressive replacement will be expected. During the pre-rounds at 6am, house-staff begin addressing any underlying fluid or electrolyte deficiencies. We then review the "morning labs" as a team during the 7am rounds and decide further treatment. Urine electrolytes should also be followed as deemed necessary by clinical judgment.

Our goals should be:

K > 4.0
Mg > 2.0
Phos > 3.5
Ion. Ca > 4.0
Alb > 2.5
Hct > 30.

Also, it is important to ensure that ALL of our patients are receiving their daily requirements of the electrolytes. Oral Potassium (at least 2 mEq/kg/day) should be the routine and can either be given in divided oral doses or added to the tube feedings (continuous replacement via tube feedings is an efficacious method of electrolyte replacement. and we are reviewing our current policies in this regard). If a patient is on diuretics, then we will need to increase the oral replacement. Oral daily Mg replacement should also become standard (either with Mg-sulfate or Mg-oxide and should range from 400mg – 1 g/day, based on the weight of the patient). If the oral form is not well tolerated, then we will need to shift towards IV replacement.

Our medical and surgical approaches have proven to significantly lower both morbidity and mortality over the past thirty years; they are aggressive and have set new standards for our field. Similarly, our routine approaches should strive for the same level of care. By successfully implementing such a system in your ICU, you can establish a far more efficient approach in regards to fluid and electrolyte management. We certainly do not wish to remove clinical judgment from the system nor create a "robotic-like" atmosphere, however we must recognize the fact that wide variations in care do exist and at times, lead to unacceptable clinical states. By establishing these guidelines, we hope to create a consistent baseline in order to improve patient safety and the overall efficiency of intensive care units.

ELECTROLYTES

I. CALCIUM

TREATMENT OF HYPOCALCEMIA

SYMPTOMS: Tetany, muscle spasms, lethargy, seizures

NORMAL LEVELS: Total Calcium: 8.4-10.2 mg/dl (2.1-2.6 mmol/L)

Ionized Calcium: 3.8-5.3 mg/dl (0.95-1.35 mmol/L)

CORRECTION FOR LOW ALBUMIN

For every 1mg/dl of albumin below 4 mg/dl, add 0.8 mg/dl to total calcium

= [(4 - alb) x 0.8] + calcium

1. Determine Ca x PO4 product in mg/dl before administering calcium. If product is greater than 60 mg/dl,

there is an increased risk of calcium phosphate precipitation in the cornea, lung, kidney, cardiac conduction system, and blood vessels.

2. Determine potassium, phosphorus and magnesium levels. If the magnesium concentration is low, it should be corrected, otherwise it will be difficult to normalize potassium and calcium.

3. Hyperkalemia and hypomagnesemia potentiate the cardiac neuromuscular irritability produced by hypocalcemia. Hypokalemia and hypermagnesemia protect against the effects of hypocalcemia.

4. For each 5 units of packed RBCs transfused, administer 1-2 gms (1-2 amps) of calcium gluconate.

5. As a guideline, the total calcium will increase by 0.5 mg/dl for every gram of calcium gluconate given intravenously.

6. Patients who develop acute hypocalcemia after parathyroidectomy, may require up to 10 gms of calcium gluconate intravenously in 1000 ml fluid at a rate of 1 gm/hr (100 ml/hr)

A. ORAL CALCIUM REPLACEMENT

*Absorption is variable and depends on PTH, Vitamin D, and gastric pH.

TRADE ELEMENTAL

FORMULARY AGENTS NAME CALCIUM

Calcium Carbonate 500 mg chewable tabs Tums® 200 mg Calcium Carbonate 650 mg tablets 260 mg Calcium Carbonate 1250 mg tablets OsCal 500® 500 mg Calcium Carb 250 mg + Vit D 125 IU/tablet OsCal 250 +D® 100 mg Calcium Glubionate syrup 1.8 gm/5ml NeoCalglucon® 115 mg/5ml Calcium acetate (Phos Lo®) is available for phosphate binding and not calcium replacement in patients with renal insufficiency since its calcium absorption is poor.

USUAL DOSE: 500- 2000 mg elemental calcium a day, in divided doses (bid-qid)

ADVERSE EFFECT: Constipation

B. INTRAVENOUS CALCIUM REPLACEMENT

Intravenous replacement should be used if severe symptomatic hypocalcemia exists (corrected calcium is <7.7 mg/dl) or if there is a high risk for complications secondary to hypocalcemia.

FORMULARY AGENTS Elemental Calcium__

Calcium chloride 10 % 1 gm/10 ml syringe 272 mg (13.6 mEq)
Calcium gluconate 10% 1 gm/10 ml ampule 90 mg (4.5 mEq)___

Repeat calcium levels can be drawn the next day or sooner, if necessary.

MAXIMUM CONCENTRATIONS: Calcium gluconate: 1 gm in 50 ml D5W or NS

Calcium chloride*: 1 gm in 100 ml D5W or NS

*Calcium chloride should not be given IM or SC because severe tissue necrosis may occur

INFUSION RATE: Infuse over 30-60 minutes. Rapid administration may cause bradycardia, hypotension and vasodilation. Infiltration of IV calcium may cause severe tissue necrosis and sloughing.

II. MAGNESIUM

TREATMENT OF HYPOMAGNESEMIA

SYMPTOMS: Irritability, confusion, arrhythmias, weakness, fasciculation's, nystagmus, seizures

NORMAL LEVELS: 1.7-2.7 mg/dl

A. ORAL MAGNESIUM REPLACEMENT

For Mg levels > 1.2 mg/dl AND asymptomatic, oral* therapy may be used:

*Oral absorption is variable with 15-50 % of a dose being absorbed.

Elemental Magnesium Usual

FORMULARY AGENTS mg mEq_____ Dose_____

MgOxide 400 mg tablets 240 20 1-2 tablets daily
MgHydroxide (MOM®) 10 ml 360 30 1-2 times a day
MgHydroxide (Maalox®) 10 ml 180 15 1-2 times a day

ADVERSE EFFECTS: Diarrhea (may be reduced by dividing daily doses)

B. INTRAVENOUS MAGNESIUM REPLACEMENT

For Mg levels < 1.2 mg/L or symptomatic or patient unable to take oral

Magnesium sulfate equivalencies: 1 gm MgSO4 =100 mg Mg= 8 mEq Mg

SYMPTOMATIC/ASYMPTOMATIC

WEIGHT OR Mg < 1.2 mg/dl AND Mg > 1.2 mg/dl < 50 kg 2-3 gm Mg Sulfate 1-2 gm Mg Sulfate >50 kg 3-4 gm Mg Sulfate 2-3 gm Mg Sulfate

Additional doses of 1-2 gms/day of Mg sulfate may be required for several days if the patient has not previously been receiving magnesium.

Renal insufficiency (CLcr < 20ml/min) may require lower doses of magnesium. Caution should be used when replacing magnesium in any patient with renal insufficiency.

MAXIMUM CONCENTRATION: 1 gm in 5 ml D5W or NS

MAXIMUM INFUSION RATE: 1 gm over 7 minutes

Magnesium sulfate may be given IM, however it can be very painful. Doses greater than 1 gm must be given in different injection sites.

For symptomatic patients, bolus doses of IV magnesium are required.

For asymptomatic patients, adding magnesium to the patient's maintenance IV fluids will allow for better retention of magnesium

Repeat magnesium levels can be drawn the next day or sooner, if necessary.

III. PHOSPHOROUS

TREATMENT OF HYPOPHOSPHATEMIA

SYMPTOMS: Anorexia, bone pain, muscle weakness, respiratory failure, CHF, hemolysis, rhabdomyolysis

NORMAL LEVELS: 2.4 - 4.5 mg/dl (0.8 - 1.5 mmol/L)

1. Determine Ca x PO4 product before administering phosphorus;

If the product is greater than 60 mg/dl, there is a risk of calcium phosphate precipitation in the cornea, lung, kidney, cardiac conduction system, and blood vessels.

A. ORAL PHOSPHORUS REPLACEMENT

For Phosphorus > 1 mg/dl (>0.3 mmol/L), oral therapy may be used:

FORMULARY Phosphorus Sodium Potassium

AGENTS mmol /mEq

Neutra-Phos® 8 7 7 per capsule/powder packet*

Neutra-Phos K® 8 0 14 per capsule/powder packet*

Skim milk per 8 oz 4 3 5

USUAL DOSE: 1-2 powder packets* or capsules* (8-16 mmol) of Neutra-Phos or Neutra-Phos K po/ng tid.

*Each Neutra-phos capsule/packet must be opened and diluted with 75 ml of water before administration.

8 oz skim milk (4 mmol of Phos) tid

ADVERSE EFFECT: Diarrhea (will decrease Mg absorption)

NOTE: Magnesium, calcium and aluminum containing antacids may bind phosphorus and prevent its absorption, so should be avoided in patients with low phosphate levels.

B. INTRAVENOUS PHOSPHOROUS REPLACEMENT

For Phosphorus < 1 mg/dl (< 0.3mmol/L), IV phosphorus should be given.

FORMULARY AGENTS Phosphorus Sodium Potassium

Potassium phosphate 3 mmol/ml 0 4.4 mEq/ml

Sodium phosphate 3 mmol/ml 4 mEq/ml 0

USUAL DOSE: For acute decreases in PO4: 0.25 mmol/kg IBW*

For chronic depletion of PO4: 0.5 mmol/kg IBW*

Renal insufficiency (CLcr <20ml/min): reduce dose by 50%

As a guideline, the phosphorus level will increase by an average of 1.2 mg/dl with a dose of 0.25mmol/kg

*IBW: Men = 50 + 2.3 (inches over 5 feet)
Women = 46 + 2.3 (inches over 5 feet)

Recommended concentrations and rate of administration:

KPhos 6 mmol / 100 ml NS or D5W over 4 hours peripherally or centrally not to exceed 15 mmol per minibag*

NaPhos 10 mmol / 100 ml NS or D5W over 4 hours

peripherally or centrally.

Maximum concentrations and rate of administration:

Use of these concentrations and rates requires continuous monitoring and is restricted to those areas which can provide that level of care except in emergent situations.

This method of administration is NOT recommended if:

total calcium is < 7.5 mg/dL or > 11 mg/dL (corrected for albumin**) phosphorus is > 2 mg/dL OR significant renal dysfunction (Clcr < 10 ml/min)

KPhos 15 mmol / 100 ml NS or D5W over 2 hours centrally.*

NaPhos 15 mmol / 100 ml NS or D5W over 2 hours centrally.

*Although 15mmol of KPhos provides 22 meq of potassium which exceeds the recommended dose of potassium per minibag (20 meq), the maximum infusion rate of 2 hours complies with current potassium administration guidelines (i.e., 20meq/100ml NS or D5W over minimum 1 hour centrally).

**Correction for low albumin: For every 1mg/dL of albumin below 4 mg/dL, add 0.8 mg/dL to total calcium:

Ca corrected = [(4- albumin) x 0.8] + Ca measured

Phosphorus levels should be drawn at the end of the infusion and should always be drawn prior to any additional doses administered.

Note: Phosphorus has historically been administered over 4 to 6 hours due to the potential risk associated with high doses and rapid administration (i.e., hypocalcemia, hypotension, metastatic calcification, renal failure). However, most of this data comes from cases of hypercalcemia treated with large doses of intravenous phosphates in which phosphorus levels were typically normal. More aggressive electrolyte replacement is not considered as risky.

IV. POTASSIUM

INTRAVENOUS POTASSIUM ADMINISTRATION

CLINICAL INFORMATION

A. Normal serum potassium value is 4.0 - 5.0 mmol/L

B. Magnesium levels should be monitored and replacement given if necessary since potassium repletion is ineffective in the presence of hypomagnesemia.

WARNINGS / PRECAUTIONS

A. Rapid infusion of KCl may cause cardiac arrest.

B. Avoid extravasation. Thrombophlebitis may result and is related to the rate, concentration and size of vein.

C. Signs and symptoms of hypokalemia (K+ < 3.5 mmol/L)

1. muscle weakness 5. hypotension
2. anorexia 6. weak pulse
3. vomiting 7. ECG changes: flattened ST segment, T wave
4. heart block, dysrhythmias inversion and U wave elevation
5. hypotension
6. weak pulse
7. ECG changes: flattened ST segment, T wave

D. Risk Factors for developing hypokalemia

1. diarrhea, vomiting
2. amphotericin B
3. diuretics
4. metabolic alkalosis
5. insulin
6. beta2 agonists (e.g., terbutaline)

E. Signs and symptoms of hyperkalemia (K+ > 5.0 mmol/L)

1. confusion 4. flaccid paralysis
2. listlessness, irritability 5. bradycardia
3. paresthesias of extremities 6. peaked T-waves on ECG, dysrhythmias
4. flaccid paralysis
5. bradycardia
6. ECG changes peaked T-waves on ECG, dysrhythmias

F. Risk Factors for developing hyperkalemia

1. renal impairment
2. use of ACE Inhibitors (captopril, enalapril, lisinopril, etc.)
3. use of potassium sparing diuretics (spironolactone, amiloride, etc.)
4. use of high dose TMP/SMX for PCP in HIV infected patients

G. Patients on digoxin are more likely to develop digoxin toxicity if K+ is low.

H. If burning or stinging sensation occurs while KCl is being given via peripheral line, the discomfort may be reduced by the following methods:

1. decrease rate of infusion
2. reduce the concentration of KCl

POTASSIUM CHLORIDE GENERAL STATEMENTS

I. Potassium chloride must never be administered by IV push or IM injection.

II. All potassium chloride infusions will be supplied by the Pharmacy Department. These infusions will be commercially prepared in minibags, or compounded by the Pharmacy. Potassium Chloride vials will not be stocked in any patient care areas. Any exceptions will need to be petitioned to the P & T Committee. In pediatric or neonatal patients, all infusions will be administered via an infusion pump and burette, or by a syringe pump.

III. All IV maintenance infusions with KCl at a concentration greater than 40 mEq/L must be administered via an infusion pump.

IV. Peripheral administration

A. In adults, the maximum concentration via peripheral line is 10 mEq/100 ml.

B. In adults, the maximum amount of KCl available in each IV minibag is 20 mEq. In nenoates or pediatrics only two hours worth of fluid volume will be added to the burette at anytime. Only one hour worth of fluid should be in a syringe pump.

C. The maximum infusion rate via peripheral line is 10 mEq per hour. In neonates and pediatrics, the maximum infusion rate via peripheral line is 0.5 - 1 meq/kg/hour.

V. Central administration

A. In adults, the preferred concentration via central line is 20 mEq/100 ml. The maximum concentration for fluid restricted patients is 20 mEq/50 ml.

B. In adults, the maximum amount of KCl available in each IV minibag is 20 mEq. In neonates or pediatrics only two hours worth of fluid volume will be added to the burette at anytime. Only one hour worth of fluid should be in a syringe pump.

C. The maximum infusion rate via central line is 20 mEq/hr. In neonates and pediatrics, the maximum infusion rate via central line is 1 meq/kg/hour.

VI. In adults, potassium levels must be checked after a total of 60 mEq has been administered. Potassium levels must be checked no sooner than 60 minutes after a given IV dose. In neonates and pediatrics, potassium levels must be checked after a total of 1 meq/kg has been administered.

ORAL POTASSIUM ADMINISTRATION GUIDELINES

A. Oral potassium chloride replacement should be considered in asymptomatic patients with serum potassium levels < 3.8 mEq/L.

B. Adult doses from 40-100 mEq/day may be required for potassium repletion given in 2 - 4 divided doses per day. In the neonate and pediatric patient, 1-3 meq/kg/day may be required for potassium repletion given in 2 - 4 divided doses per day.

C. In adults, start with 20-40 mEq/day and titrate to desired level. A 40 mEq dose may be given every 2 hours for a maximum dose of 120 mEq within a 6 hour period. In the neonate, start with 0.5 - 1 meq/kg/day and titrate to desired level with the maximum dose of 3 meq/kg within a 6 hour period.

D. When oral potassium therapy is combined with parenteral supplementation for adults, a maximum total dose (IV + PO) is 120 mEq within a 6 hour period. For the neonate, a maximum total dose (IV + PO) is 3 meq/kg within a 6 hour period.

E. Do not use sustained release potassium products, (e.g.,

KDur™) when an immediate response is desired. The potassium chloride powder, dissolved in water, or potassium chloride solution, should be used for a quicker response.

F. Potassium levels must be checked after each replacement dose. If using immediate release preparations (KCl powder), a level should be checked no sooner than 60 minutes. If using a sustained release product, a level should be checked no sooner than 3 hours. Patients receiving maintenance doses of oral potassium do not require levels after each dose.

References

Author Information

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