

JOINT TRAUMA SYSTEM CLINICAL PRACTICE GUIDELINE (JTS CPG)



Hyperkalemia and Dialysis in the Deployed Setting (CPG ID: 52)

Provides recommendations for the management of patients with, or at risk for, acute kidney injury and hyperkalemia in the deployed environment.

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SUMMARY OF CHANGES

1. Medical management for hyperkalemia flow chart and table.
2. Increase in treatment threshold to a K of 6.0 from 5.5 in tracking metrics.
3. Continuous Renal Replacement Therapy (CRRT) modality change from Continuous Venovenous Hemofiltration (CVVH) to Continuous Venovenous Hemodialysis (CVVHD).
4. CCRT flow chart.
5. Drug dosing recommendations for CVVHD.
6. Anticoagulation recommendation for CVVHD.
7. Recommendation for nutrition.
8. Addition of oral potassium binders.
9. Removed use of sodium bicarbonate for hyperkalemia.
10. Improvised dialysate fluid for CRRT and peritoneal dialysis.
11. Assessing fluid status recommendations.

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BACKGROUND

Acute kidney injury (AKI) is a recognized complication of combat trauma. According to the Department of Defense Trauma Registry (DoDTR) data, AKI was listed as a complication in 0.6% of combat casualties. This is likely an under-representation of the real incidence as it was required to be listed as a complication in the available documentation. Smaller studies from two Role three facilities in theatre show AKI after combat trauma occurs in up to 34.3% of the most critically injured patients, usually within the first two days after injury.¹ This is likely closer to the real incidence in severely injured patients as a more thorough definition of AKI was used and is described below. Review of the DoDTR data did capture the number of patients that required renal replacement therapy (RRT) either in the form of continuous venovenous replacement (CRRT) or peritoneal dialysis (PD). Of the 558 patients with AKI listed as a complication, 112 or 20% required renal replacement. Of these 112 patients, 35 or 31% required RRT while still in theatre. In the recent conflicts in Iraq and Afghanistan, rapid evacuation out of theater ensured that the complications of AKI (including hyperkalemia) occurred further up the evacuation chain (Role 3-4), where RRT may have been available;² Furthermore, rapid damage control resuscitation and surgery likely decreased the rate of severe AKI. As a consequence, there are no recent data on the frequency of hyperkalemia following AKI in theater when experiencing delays in treatments and evacuations. However, evidence from prior conflicts suggests that up to one-third of combat casualties with oliguric renal failure developed severe hyperkalemia within four days of injury.³ In future operations, military providers should be prepared for prolonged evacuation times.⁴ AKI and life threatening hyperkalemia may be encountered at Role 3 facilities more frequently, where RRT is limited or non-existent. This is an important planning factor in future Large Scale Combat Operations (LCSO) where there may be multiple Role 3s and limited availability to move casualties compared to the previous conflict. AKI is classified by relative changes in creatinine and can be diagnosed with as little as a 0.3mg/dL increase in creatinine over a 48 hour (hr) period.⁵ AKI can also be determined by decreased urine output (< 0.5 ml/kg/hr for at least 6 hours). While mild AKI can generally be managed with supportive care; more severe AKI [characterized by oliguria (<500 ml/day of urine output and/or <0.5 mL/kg/hr) or a doubling of serum creatinine] may require RRT. Therefore, providers caring for patients in austere or deployed environments should monitor patients for AKI and be prepared to expedite evacuation to a higher echelon of care, when necessary.

RECOMMENDATIONS

These recommendations are intended to temporize patients until they can be evacuated to a higher echelon of care with the full range of RRT capabilities.

ETIOLOGY OF HYPERKALEMIA

Providers in the operational setting should be proactive in correcting hyperkalemia. Rhabdomyolysis, dehydration (especially in the setting of Non-steroidal anti-inflammatory drugs), hypotension, packed red blood cells transfusions, sepsis, and urinary obstruction are a few causes of hyperkalemia encountered in the deployed setting.

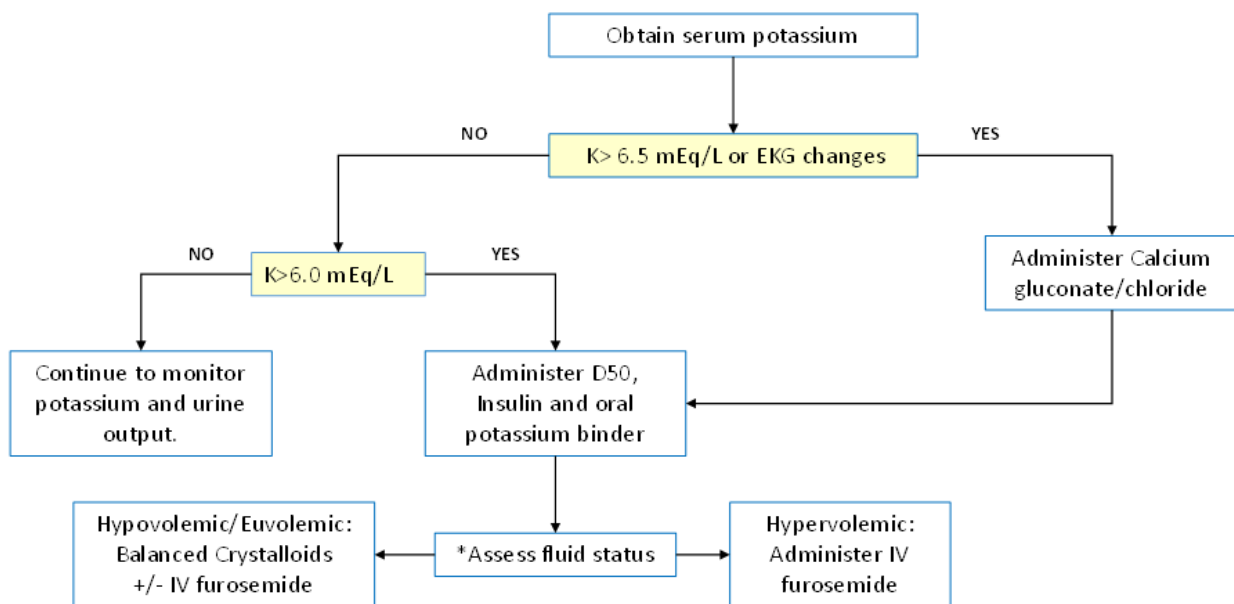
MONITORING

Monitor serum potassium, serum creatinine, hourly urine output, and an electrocardiogram (if available) in patients at risk for AKI and hyperkalemia.

MEDICAL MANAGEMENT

Medical therapy is the first step of AKI management with hyperkalemia. This includes cardiac membrane stabilization (with intravenous calcium chloride or calcium gluconate) and/or shifting potassium intracellularly (with insulin and glucose or a β -2-adrenergic agonist). Consider maneuvers to remove potassium with diuretics and potassium binding agents; usage may be limited by hemodynamic status, anuria, and bowel injuries. We suggest shifting potassium intracellularly when the potassium is greater than 6.0 milliequivalents per liter (meq/L) [with intravenous insulin and 50 percent dextrose (D50), with or without albuterol]. Take into account the clinical situation when determining when to treat hyperkalemia. For example, a rapid rise or impending evacuation should prompt consideration for shifting at a lower cut-off (i.e. 5.5meq/L). Calcium should be given if there is evidence or suspicion of clinically significant hyperkalemia and evidence of altered conduction on electrocardiogram such as: peaked T waves, widened QRS, flattened P waves, bradycardia, ventricular tachycardia, ventricular fibrillation, right and left bundle block, pseudo infarct, and Brugada pattern.^{6,7,8} Calcium should also be considered empirically for a potassium concentration >6.5 meq/L. See [Appendix A](#) for a list of medications, routes of administration and recommended treatment order. The use of Balanced Crystalloids in the setting of hyperkalemia may seem contraindicated. However, through volume of distribution administering a potassium containing fluid which is lower than the patient's serum potassium will in fact lower the serum potassium concentration.⁹ Providing a hyperchloremic crystalloids such as 0.9% normal saline will result in mineral acidosis thus worsening hyperkalemia.¹⁰

Figure 1. Medical management for hyperkalemia



*see [Appendix E](#) on assessing fluid status

Table 1. Medical management for hyperkalemia

	Access	Monitoring	Therapies	Other Comments
Good	<ul style="list-style-type: none"> ▪ 2 Large Bore IVs 	<ul style="list-style-type: none"> ▪ Frequent Clinical Checks ▪ Frequent Vital Signs ▪ Monitor urine output 	<ul style="list-style-type: none"> ▪ Calcium ▪ Balanced Crystalloids* 	Crystalloids if no contraindication such as uncontrolled hemorrhage
Better	<ul style="list-style-type: none"> ▪ 2 Large Bore IVs ▪ Foley Catheter 	<ul style="list-style-type: none"> ▪ Frequent Clinical Checks ▪ 12 lead EKG ▪ Foley to monitor urinary output (UOP) ▪ Glucometer 	<ul style="list-style-type: none"> ▪ Calcium ▪ Balanced Crystalloids* ▪ D50/Insulin ▪ Albuterol(neb) ▪ Furosemide 	Note that in the absence of potassium monitoring, these would only be considered if characteristic EKG or peri-arrest patient with high clinical suspicion.
Best	<ul style="list-style-type: none"> ▪ 1-2 Large Bore IVs ▪ Central Venous Catheter ▪ Foley Catheter 	<ul style="list-style-type: none"> ▪ Frequent Clinical Checks ▪ Continuous EKG Monitoring ▪ 12 lead EKG ▪ Foley to monitor UOP ▪ Glucometer ▪ Point-of-care labs 	<ul style="list-style-type: none"> ▪ Calcium ▪ Balanced Crystalloids* ▪ D50/Insulin ▪ Albuterol (neb) ▪ Furosemide ▪ Potassium binder 	Use caution with furosemide as this may exacerbate hypotension in acute resuscitative phase. See Figure 1 flow chart.

*Balance Crystalloids= Lactated Ringers or Plasmalyte ®

FAILURE OF MEDICAL MANAGEMENT

In the experience of the authors, the most common reason for starting RRT for patients with AKI in the deployed setting is hyperkalemia resistance to medical management. A potassium level greater than 6 meq/L, despite medical management, should prompt consideration of RRT with either the NxStage System One or acute PD. Occasionally, patients may require RRT in theater for other indications, such as acidemia or severe volume overload. The following detailed methods can effectively temporize patients with these indications as well.

SEVERE HYPERKALEMIA & NXSTAGE SYSTEM ONE

If available, use the NxStage System One for severe hyperkalemia that does not respond to medical management. To utilize this system, the patient must have central venous access with a dialysis catheter, the machine must be setup and the prescription must be entered. There are five components to a CRRT prescription: mode, blood flow rate, replacement fluid, replacement fluid rate, and ultrafiltration rate. See [Appendix C](#) for a suggested initial prescription.

Central Venous Access

Place a hemodialysis catheter, prior to initiation. In terms of location, follow guidelines,⁵ which suggests the first choice of access is the right internal jugular vein (with a 12-14 French, 15cm catheter), because this location has been associated with the lowest rates of catheter dysfunction.¹¹ The second choice is the femoral vein (with a 20-25cm catheter). The last choice is the left internal jugular vein (with a 20cm catheter) because it is associated with the highest rates of catheter dysfunction.¹¹ If possible, avoid the

subclavian veins. Lines in this location often result in subclavian stenosis, which can complicate or preclude future dialysis access in patients at risk for the development of end stage renal disease.^{12,13}

Setup

The Set up – Initiate – Make connections – Program – Launch treatment – End (SIMPLE) instructions are displayed on the NxStage computer screen once the machine is turned on. These instructions are quite detailed and, if followed closely step-by-step, will guide the provider through priming the cartridge, putting the patient on the machine, entering the prescription and ending the treatment once it is complete. Ideally, providers that deploy to a location with the NxStage System One should receive training on the setup and use of the system prior to deployment. The instructions are straightforward enough to allow an inexperienced physician or nurse to perform a treatment within the deployed setting.

Mode

The NxStage System One can provide continuous venovenous hemodialysis (CVVHD), which is the recommended form of CRRT for the down-range setting. Complete this by connecting the two green ports as specified in the step-by-step priming instructions.

Blood Flow Rate

The minimum blood flow rate is 200ml/minutes (min) and should be increased to 400ml/min if possible. A faster blood flow rate will decrease the likelihood of blood clotting the filter. The most common limitation for increasing the blood flow rate is the pressure required to draw blood out of the dialysis catheter. If this pressure becomes too negative, the machine will alarm and stop the treatment. This alarm is often due to catheter port suction against the vessel wall. If this occurs, decrease the blood flow rate until the machine no longer alarms. Catheter manipulation, line reversal, or line relocation may solve this issue. To manipulate the catheter, using the sterile technique, grasp the catheter proximal to the sutured/secured hub and twist it 180 degrees. This may move the blood flow ports away from a vessel wall. To reverse the lines, first stop the machine and clamp both the blood lines and both the dialysis catheter ports. Then disconnect the blood lines and re-connect them to the dialysis catheter ports opposite of how they were previously connected. If these efforts fail, consider an alternate insertion site for the catheter.

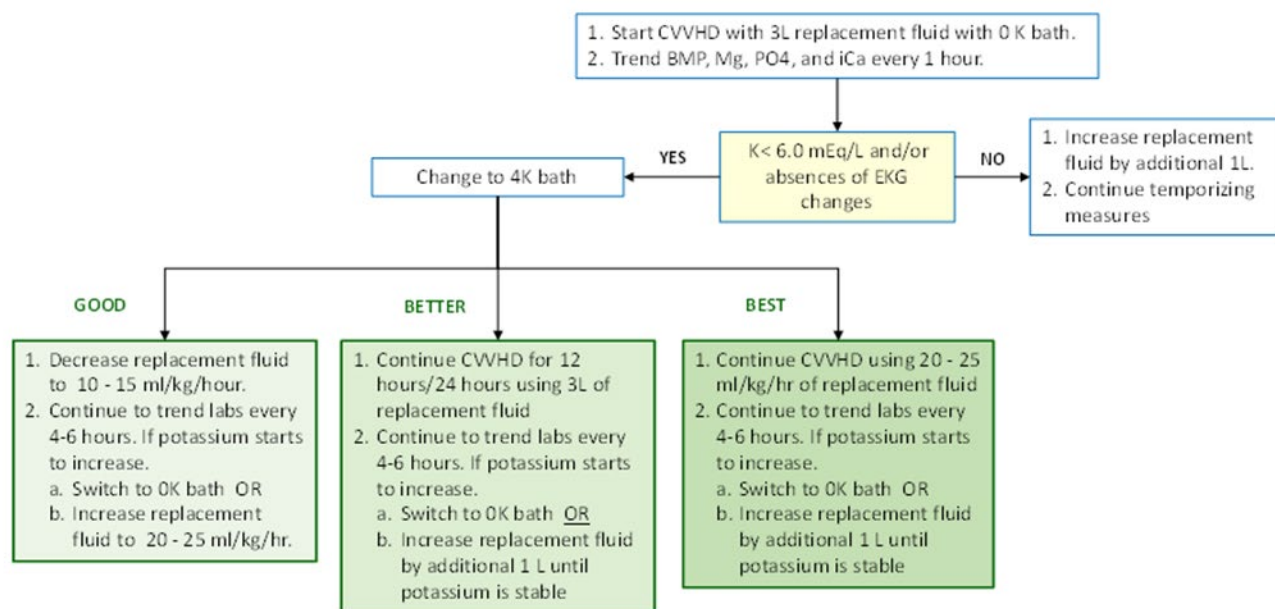
Dialysate Fluid

There are several commercially made replacement fluids. Regardless of the specific brand available, there will be 0meq/L potassium (0K) and 4meq/L potassium (4K) options. Since CRRT in the deployed environment is usually initiated for hyperkalemia, we suggest starting with the 0K fluid and following the potassium concentration every hour. Once the potassium decreases to <6.0 meq/L and/or absences of EKG changes, the patient can be transitioned to the 4K replacement fluid. It is important to note that the replacement fluid bags have two separate compartments, to avoid precipitation of calcium and bicarbonate. It is vital that the seal between the two compartments is broken in the manner detailed in the step-by-step instructions on the NxStage System One display screen. If commercial solutions are not available, replacement fluids can be made (See [Appendix E](#)).¹⁴ Despite which fluid is in use, closely monitor ionized calcium, magnesium and phosphate (every 6 hours) if possible and replace as needed.

Dialysate Flow Rate

The dialysate flow rate is the rate at which the machine infuses dialysate fluid and it is the primary determinant of clearance. Initially, we suggest starting with a dialysate flow rate of 3L/ hour with hourly monitoring of serum potassium. If the potassium fails to improve, increase the dialysate flow rate. With the NxStage System One, the maximum dialysate flow rate is dependent on the blood flow rate. If high clearances are needed, increase the blood flow rate to 400ml/min and set the dialysate flow rate as high as the machine allows (8.4L per hour). If this fails, the patient likely has severe ongoing tissue necrosis and you need to consider surgical re-evaluation for debridement. Reduce the dialysate flow rate or consider stopping CVVHD once you have reached a reasonable serum potassium level in order to conserve resources.

Figure 2. CRRT management for hyperkalemia



Ultrafiltration Rate

This is the rate at which the machine removes volume from the patient. For example, if this is set at 100ml/hr, 2.4L will be removed from the patient over the next 24 hours. In the absence of overt hypervolemia, we suggest initially setting the ultrafiltration rate to 0 or equal to all of the patient's hourly fluid input (IV fluids, antibiotics, etc.). However, if the patient has significant volume overload (e.g., pulmonary edema), this can be titrated to achieve a net negative fluid balance of 1-2L per day (all quantifiable inputs minus all quantifiable outputs).

Since these patients have experienced recent trauma, often with associated coagulopathy, and citrate anticoagulation is not available in the deployed setting, we suggest not anticoagulating patients for the sole purpose of CRRT. Should filter clotting become an issue, the following maneuvers may be useful: 1) increase blood flow rate or 2) decreasing/stopping ultrafiltration rate to decrease hemo-concentration. Another strategy that is considered safe is adding a pre-filter (into the blood line coming out of the patient and going to the NxStage System One) infusion of normal saline at 100 ml/hr (you need to account for this input when calculating ultrafiltration rate) to help dilute blood in dialyzer. As a

last resort and only if there is recurrent clotting compromising the delivery of this therapy and the patient is not a bleeding risk, you may consider an infusion of 500 units per hour of heparin. This should be infused pre-filter as previously noted. If needed, this can then be titrated to achieve an aPTT 1.5-2 times normal.¹⁵

DRUG DOSING

General antimicrobial dosing for CVVHD (recommendations below in Table 2 are based on data using CVVH, possible increase in drug clearance with CVVHD modality).

Table 2. General antimicrobial dosing for CVVHD

Antibiotic	Recommend dose for CVVHD
Vancomycin	20 mg/lg/24hrs as continuous infusion
Daptomycin	8 mg/kg every 48 hours
Piperacillin/Tazobactam	3.375 g every 6 hours, each dose infused over 3 hours
Cefepime	Loading dose of 2,000 mg followed by 1,000-2000 mg every 12 hours
Meropenem	1 g every 8 hours
Imipenem/cilastatin	500 mg every 6 hours
Amikacin	Loading dose of 10 mg/kg, then 7.5 mg/kg every 24-48 hours
Levofloxacin	Loading dose of 500-750 mg then 250 mg every 24 hours

NUTRITION

Patients on CRRT have an increased nutritional demand due to clearance delivered by CRRT. Higher dose clearance requires increased nutrient demands.

Table 3. Nutritional recommendations for patients on CRRT

	Recommendation	Notes
Energy requirements	25-35 Kcal/kg	Fluids containing lactate, citrate, and acetate can also contribute to caloric intake.
Protein Requirements	1.5 g/kg/day	Can consider glutamine supplementation 0.3-0.5 g/kg/day. If BUN continues to rise despite CRRT consider reduction in protein intake.

ACUTE PD

If patients do not respond to medical management, and NxStage System One is not available, consider acute PD.

While its use has been supplanted by CRRT in most developed nations, PD is an established treatment for AKI with electrolyte disturbances such as hyperkalemia.¹⁶ PD relies on the diffusion and convection of solutes from the blood into a fluid across the peritoneal membrane. For the purposes of potassium clearance, a fluid that is low in potassium is infused into the peritoneal space. Potassium then flows down its concentration gradient from the blood and extracellular space into this fluid. Once equilibration is achieved (i.e. the concentration in the blood and fluid are equal) no further potassium goes into the fluid. Therefore, the fluid must be exchanged periodically to maintain clearance.

Because recent abdominal surgery is considered a relative contraindication to PD,¹⁷ the efficacy of PD and the complications associated with PD in trauma patients that have undergone laparotomy and/or have bowel in discontinuity are largely unknown. However, there are case reports of PD being used in combat casualties with recent laparotomy.²⁰ If no other forms of renal replacement therapy are available and the patient cannot be evacuated to a higher echelon of care, consider PD, even in patients without an intact peritoneal lining.

In order to perform PD, access to the peritoneal space is needed. Once access is established, there are three components to a PD prescription: fluid type, exchange volume, and dwell time.

Catheter Placement

Under normal circumstances, specialized catheters are used for PD. These are not usually available in the deployed setting, which require available supplies to be repurposed. Jackson-Pratt (JP) abdominal drains and pediatric chest tubes have both been used as improvised PD catheters in theater.^{18,20} Nasogastric tubes central lines, suprapubic and urinary catheters have also been recommended as improvised catheters.^{16,18} While catheters can be placed via a variety of methods (including modified Seldinger and laparoscopic techniques), most patients in the forward deployed environment will require open surgical approaches.²⁰ Under ideal circumstances, PD catheters should be tunneled in order to decrease the risk of peritonitis.¹⁶ This may not be an option in the austere, forward deployed environment where the use of stoma appliances as a protective dressing to prevent the described infections.²⁰

Fluid Type

While specialized PD fluids are made commercially, they are not normally available in deployed locations. However, a variety of fluids can be used for field expedient PD (Refer to [Appendix D](#) for this section). If the indication is hyperkalemia, use a solution with a potassium concentration of 0 at the initiation of PD. Monitor the patient's potassium level and once normalized, change the fluid to a concentration of ~4meq/L by using one of the alternate fluids. Note that in the setting of shock or liver failure, a solution with bicarbonate (not lactate) will reverse acidemia more rapidly.¹⁹ If acidemia persists after correction of potassium in patients in shock, ~4meq/L of potassium should be added to the "potassium free solution" of choice to avoid using lactate as a buffer. The amount of fluid removed by PD is determined by two factors: 1) the amount of time the fluid is in the abdomen and 2) the concentration of dextrose in the solution. As others have recommended,¹⁵ we suggest that a concentration of ~1.5% dextrose be used for patients that are euvolemic or hypovolemic. For patients that are moderately or severely volume overloaded, we suggest ~2.5% and ~4.5% dextrose concentrations, respectively. Note that a 4.5% dextrose fluid can remove volume very quickly (up to 1L in 4 hours),¹⁵ therefore you should limit its use to hemodynamically stable patients with severe, life-threatening pulmonary edema.

Exchange Volume

The "exchange volume" is the volume of fluid infused into the peritoneal space. Removing the fluid after the dwell and instilling fresh fluid is referred to as an "exchange." We recommend starting with a volume of 1L per exchange for and then increasing to 2L per exchange if tolerated. We recommend continuous exchanges until potassium is <6.0 mEq/L; then can decrease to 5 cycles of 2L exchanges. The volume infused may be limited by fluid leakage around the surgical site, especially in patients with large laparotomy incisions or open abdomens. To avoid leakage, keep the patient in the supine position during PD.

Dwell Time

The length of time that the fluid is allowed to sit in the peritoneal space between exchanges is known as the “dwell time.” We recommend frequent exchanges (defined as an initial dwell time of 1 hour) until the initial therapeutic goal has been achieved (e.g., potassium normalized or acidemia reversed), at which point the dwell time can be extended to every 2-4 hours with close monitoring.

In the forward deployed setting, the use of PD can be complicated by fluid leakage (especially if the abdomen must be left open) and also by the development of abdominal compartment syndrome with fluid infusion. These may severely limit the volume of fluid that can be infused and allowed to dwell. In this case, the fluid can be continuously exchanged.²⁰ In practice, this means instilling fluid into the peritoneum from one site (e.g., from a pediatric chest tube or JP drain) while simultaneously removing fluid from another site (e.g., a different drain, or wound vac if available.) If continuous exchange of fluid is utilized, the inflow and outflow ports in the peritoneal space should be physically separated as much as possible to maximize the surface area that the fluid passes by as it goes from the inflow catheter to the outflow catheter. The outflow port should if possible be in the most dependent part of the abdomen (the pelvis).

PERFORMANCE IMPROVEMENT (PI) MONITORING

POPULATION OF INTEREST

Patients with acute kidney injury or hyperkalemia (potassium > 6.0 or hyperkalemia diagnosis code or documentation of EKG changes consistent with hyperkalemia).

INTENT (EXPECTED OUTCOMES)

1. All patients with K > 6.0 and/or EKG changes consistent with hyperkalemia receive appropriate medical treatment at the same level of care where diagnosed. (See drugs listed in [Appendix A.](#))
2. All patients with persistent hyperkalemia despite medical management receive RRT (CRRT or peritoneal dialysis) or documenting why RRT is not implemented.
3. Indication for initiation RRT is documented.

PERFORMANCE/ADHERENCE MEASURES

- Number and percentage of patients in the population of interest who receive medical treatment for hyperkalemia at the same level of care where diagnosed.
- Number and percentage of patients who receive RRT who have the indication for RRT documented.

DATA SOURCES

- Patient Record
- Department of Defense Trauma Registry

SYSTEM REPORTING & FREQUENCY

The above constitutes the minimum criteria for PI monitoring of this CPG. System reporting will be performed annually; additional PI monitoring and system reporting may be performed as needed.

The system review and data analysis will be performed by the JTS Chief and the JTS PI Branch.

RESPONSIBILITIES

It is the trauma team leader's responsibility to ensure familiarity, appropriate compliance and PI monitoring at the local level with this CPG.

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APPENDIX A: INITIAL MEDICAL MANAGEMENT FOR HYPERKALEMIA

Drug/Treatment	Dose & Route of Administration	Mechanism of Action	Time to Onset	Duration of Effect	Caution/Contraindication	Other Comments
Stabilize Cardiac Membranes						
Calcium gluconate	1000mg=one 10ml "amp" of 10% (100mg/mL) solution; infused IV over 2-3 mins	Stabilizes myocyte membrane electrical activity	Immediate	30-60 mins	Caution if pre-existing hypercalcemia	Can be administered via peripheral IV; repeat in 5 mins for persistent EKG changes
Calcium chloride	1000mg=one 10ml "amp" of 10% (100mg/mL) solution; infused IV over 2-3 mins	Stabilizes myocyte membrane electrical activity	Immediate	30-60 mins	Administration via central line preferred (can damage small vessels, cause tissue necrosis); caution if pre-existing hypercalcemia	Repeat in 5 mins for persistent EKG changes
Shift Potassium Intracellularly						
Insulin, regular	Give 50 mL 50% dextrose first unless blood glucose is >250. Then give insulin 10 units by IV bolus.	Shifts potassium intracellularly by way of Na-K ATPase pump	10-20 mins	4-6 hr	Caution if hypoglycemia. Insulin is renally secreted in setting of anuria/oliguria can cause prolonged hypoglycemia.	Check blood glucose within one hour of administration. If oliguric/anuric can consider starting D5W gtt to prevent hypoglycemia. Insulin should be kept cold until use, consider packing in personnel insulin carriers.
Albuterol	10 mg nebulized, over 10 mins	Shifts potassium intracellularly by way of Na-K ATPase pump	20-30 mins	1-2 hr	Can cause tachycardia	Has additive effect with insulin tx
Potassium Binders						
BEST Sodium Zirconium Cyclosilcate (Lokelma)	10 gram (in water) PO TID for 48 hours, followed by 10 g PO daily	Mechanism not fully understood, exchanges hydrogen and sodium for potassium in small and large intestines	1 hour	Variable (up to 48 hrs of treatment time)	No studies conducted on patient with bowel obstruction or impaction. Avoid in patients with severe constipation, bowel obstruction or impaction.	Preferred oral potassium binder Monitor for signs of edema, can increase diuretics if indicated.
BETTER Patiromer (Veltassa)	8.4 g/16.8g (in water) PO once daily	Increases potassium removal by fecal excretion, exchanges calcium for potassium in the large intestine.	~7 hours	24 hours	Avoid in patient with bowel obstruction or severe constipation. Can cause Hypomagnesemia.	May decrease effectiveness of oral Ciprofloxacin. Administer Ciprofloxacin 3 hours before or after Patiromer. Patiromer must be refrigerated or used within 3 days after removed from refrigeration.
GOOD Sodium polystyrene sulfonate (Kayexalate)	30 grams PO	Exchanges sodium for potassium in the large intestine	>2 hours	Variable	Case reports of colonic necrosis; avoid in setting of bowel obstruction or following bowel injury or surgery; may be of limited utility in setting of severe hyperkalemia.	Can repeat every 4-6 hours; consider initial dose of 45-60 grams in body weight >80 kg
Promote Kaliuresis						
Furosemide	40mg IV	Impairs renal potassium reabsorption	5 mins	2 hours	If hypotensive or volume depleted consider administration with balanced crystalloid and IV diuretics.	May require larger doses (up to 200mg) or be ineffective in setting of acute kidney injury.

APPENDIX B: CONTINUOUS RENAL REPLACEMENT THERAPY - NXSTAGE SYSTEM ONE**Suggested starting prescriptions and dosage**

	Recommendation	Notes
Mode	CVVHD	CVVHD should be considered over CVVH because it is more efficient per liter of volume used.
Blood Flow Rate	200-400 ml/min	The blood flow rate should be increased as much as tolerated by the access pressures and machine alarms to avoid clotting. We suggest maintaining flows of at least 200 cc/min.
Replacement Fluid Type	0K, 4K	If 0K or 4K fluid is not available, CRRT can be performed using lactated ringer, Plasmalyte or the improvised solutions for peritoneal dialysis. Monitor BMP, magnesium, ionized calcium, and phosphate.
Replacement Fluid Rate	3L per hour initially	See flow chart under replacement fluid rate for further guidance.
Ultrafiltrate Rate	0 ml/min	If desired, fluid can be removed via ultrafiltration. In the acute setting, barring overt hypervolemia, fluid removal should be avoided. However, consider setting the ultrafiltration rate to the patient's hourly "In's" to avoid hypervolemia.

APPENDIX C: IMPROVISED SOLUTIONS - CONTINUOUS RENAL REPLACEMENT THERAPY

	0.45% NaCl	8.4% NaHCO ₃	50% Dextrose	3% NS	50% MgSO ₄	CaCl ₂
Volume (mL)	1000	40	2.5	80	0.3	2.5

* Note that this fluid does not contain potassium or phosphate supplementation.

APPENDIX D: IMPROVISED SOLUTIONS FOR PERITONEAL DIALYSIS

Starting Fluid	Addition(s)	Ending Concentrations
Potassium Free Solutions		
1 Liter ½ Normal Saline Na 77 mEq/L, Cl 77 mEq/L	40ml of 8.4% Bicarbonate 35ml of 50% Dextrose 60ml of 3% Saline	Na 130 mmol/L, K 0 mmol/L, Ca 0 mg/dL, Cl 95 mmol/L, bicarbonate 35 mmol/L, Osm 338 mOsm/kg, Dextrose 1.54%
1 Liter ½ Normal Saline Na 77 mEq/L, Cl 77 mEq/L	40ml of 8.4% Bicarbonate 60ml of 50% Dextrose 65ml of 3% Saline	Na 129 mmol/L, K 0 mmol/L, Ca 0 mg/dL mmol/L, Cl 95 mmol/L, bicarbonate 34, Osm 388 mOsm/kg, Dextrose 2.57%
1 Liter ½ Normal Saline Na 77 mEq/L, Cl 77 mEq/L	43ml of 8.4% Bicarbonate 105ml of 50% Dextrose 75ml of 3% Saline	Na 130 mmol/L, K 0 mmol/L, Ca 0 mg/dL, Cl 94 mmol/L, bicarbonate 35 mmol/L, Osm 476 mOsm/kg, Dextrose 4.29%
Potassium Containing Solutions		
1Liter Lactated Ringers Na 130 mEq/L, K 4 mEq/L, Ca 2.7 mEq/L, Cl 109 mEq/L, Lactate 28, Osm 273 mOsm/L	30ml 50% Dextrose	Na 126 mmol/L, K 3.9 mmol/L, Ca 2.6 mg/dL, Cl 106 mmol/L, Lactate 27 mmol/L, Osm 339 mOsm/kg, Dextrose 1.46%
1Liter Lactated Ringers Na 130 mEq/L, K 4 mEq/L, Ca 2.7 mEq/L, Cl 109 mEq/L, Lactate 28 mEq/L, Osm 273 mOsm/L	53ml of 50% Dextrose 10ml of 3% Saline	Na 127 mmol/L, K 3.8 mmol/L, Ca 2.5 mg/dL, Cl 107 mmol/L, Lactate 26 mmol/L, Osm 392 mOsm/kg, Dextrose 2.49%
1Liter Lactated Ringers Na 130 mEq/L, K 4 mEq/L, Ca 2.7 mEq/L, Cl 109 mEq/L, Lactate 28 mEq/L, Osm 273 mOsm/L	95ml of 50% Dextrose 25ml of 3% Saline	Na 128 mmol/L, K 3.6 mmol/L, Ca 2.4 mg/dL, Cl 109 mmol/L, Lactate 25 mmol/L, Osm 481 mOsm/kg, Dextrose 4.24%

*1L fluid bags may contain extra fluid (40-60ml), this additional volume is not included in these calculations as it will not make a significant clinical difference.

These suggested fluids are based on what is likely to be available in the forward deployed setting. In case other fluids need to be improvised, an example of how these solutions were derived may be instructive. These calculations are based on the total amount of the substance divided by the total volume. For example, the Na concentration in the first fluid in the table:

1. Total amount of Na: amount in ½ NS (77meq/L x 1L=77meq) plus amount in 8.4% bicarbonate (1000meq/L x 0.04L= 40meq) plus amount in 3% saline (513meq/L x 0.06L= 30.78meq). Therefore, total amount is 77+40+30.78=147.78. Note that there is no Na in 50% dextrose.
2. Total volume: Volume of ½ NS plus volume of 8.4% bicarbonate plus volume of 50% Dextrose plus volume of 3% saline. 1+0.04+0.035+0.06=1.135 L.
3. Dividing the total amount of Na (147.78 meq) by the total volume (1.135L) equals 130.20264 or about 130 meq/L.

APPENDIX E: ASSESSING FLUID STATUS

	Hypervolemia	Euvolemia	Hypovolemia
Cardiovascular	Normotension/Hypertension, Strong Peripheral Pulses, Negative PLR test, Peripheral Edema*	Normotension, Normal Peripheral Pulses, indeterminate PLR	Hypotension, Weak/diminished Peripheral Pulses, Positive PLR test, Pallor, Tachycardia
Pulmonary	Crackles, Dyspnea, Pulmonary Edema, Pleural Effusion*	Eupnea, Clear Breath Sounds	No specific findings
Ultrasound Findings	Pulmonary B lines, Inferior Vena Cava (IVC) remains completely dilated on inspiration, Pleural Effusion*, Ascites*	Pulmonary A lines, Sea Shore Sign, Inferior Vena Cava (IVC) compresses less than 50% on inspiration	Positive eFAST exam, Collapsing or “Kissing” ventricles, IVC compresses more than 50% on inspiration

*- indicates late findings

PLR= Passive Leg Raise. To conduct PLR: while patient is lying flat obtain blood pressure, then raise legs to 45 degrees and hold for 60-90 seconds. After holding for 60-90 seconds obtain blood pressure. Positive PLR test is when difference of systolic blood pressures from diastolic blood pressures is equal to or greater than 10%.

Limitations: Intra-abdominal hypertension, head trauma/increased ICP, lower extremity Deep vein thrombosis (DVT), amputated leg.

Assessing volume status is difficult, even among medical professionals. The above stated clinical and imaging findings are used to serve as a guideline and volume status cannot be determined based on one sole finding, rather a combination of clinical and imaging findings.

APPENDIX F: INFORMATION REGARDING OFF-LABEL USES IN CPGS

PURPOSE

The purpose of this Appendix is to ensure an understanding of DoD policy and practice regarding inclusion in CPGs of “off-label” uses of U.S. Food and Drug Administration (FDA)–approved products. This applies to off-label uses with patients who are armed forces members.

BACKGROUND

Unapproved (i.e. “off-label”) uses of FDA-approved products are extremely common in American medicine and are usually not subject to any special regulations. However, under Federal law, in some circumstances, unapproved uses of approved drugs are subject to FDA regulations governing “investigational new drugs.” These circumstances include such uses as part of clinical trials, and in the military context, command required, unapproved uses. Some command requested unapproved uses may also be subject to special regulations.

ADDITIONAL INFORMATION REGARDING OFF-LABEL USES IN CPGS

The inclusion in CPGs of off-label uses is not a clinical trial, nor is it a command request or requirement. Further, it does not imply that the Military Health System requires that use by DoD health care practitioners or considers it to be the “standard of care.” Rather, the inclusion in CPGs of off-label uses is to inform the clinical judgment of the responsible health care practitioner by providing information regarding potential risks and benefits of treatment alternatives. The decision is for the clinical judgment of the responsible health care practitioner within the practitioner-patient relationship.

ADDITIONAL PROCEDURES**Balanced Discussion**

Consistent with this purpose, CPG discussions of off-label uses specifically state that they are uses not approved by the FDA. Further, such discussions are balanced in the presentation of appropriate clinical study data, including any such data that suggest caution in the use of the product and specifically including any FDA-issued warnings.

Quality Assurance Monitoring

With respect to such off-label uses, DoD procedure is to maintain a regular system of quality assurance monitoring of outcomes and known potential adverse events. For this reason, the importance of accurate clinical records is underscored.

Information to Patients

Good clinical practice includes the provision of appropriate information to patients. Each CPG discussing an unusual off-label use will address the issue of information to patients. When practicable, consideration will be given to including in an appendix an appropriate information sheet for distribution to patients, whether before or after use of the product. Information to patients should address in plain language: a) that the use is not approved by the FDA; b) the reasons why a DoD health care practitioner would decide to use the product for this purpose; and c) the potential risks associated with such use.