

PFC WG Fluid Therapy Recommendations

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Background:

The Prolonged Field Care Working Group (PFC WG) concurs that fresh whole blood (FWB) is the fluid of choice for patients in hemorrhagic shock, and the capability to provide a transfusion should be a basic skill set for SOF Medics. (See PFC Position Statement: PFC Capabilities). Additionally, Prolonged Field Care (PFC) must address both *resuscitative* and *maintenance* fluid requirements in *non-hemorrhagic conditions* such as significant burns, dehydration, sepsis and head injury.

There has been great debate regarding the use of colloids versus crystalloids as both fluid classes have advantages and disadvantages. The best fluid, however, is THE ONE YOU HAVE AVAILABLE. We hope to inform the community to help recommend modifications for training and logistics *and* to provide information for best decision-making, both prior to a mission and during patient treatment.

Urine output (UOP) is a very easy, and extremely important, monitoring tool to guide fluid resuscitation and fluid maintenance requirements. We recommend that PFC providers be trained and equipped to accurately measure urine output.

The type and amount of fluids given must be tailored to the specific patient being treated. These recommendations are meant to serve as a general guide, but specific guidance, via telemedicine or calling for other medical consultation, may be required in complicated, critically-ill patients with prolonged evacuation times.

Clinical Overview:

Fluid is administered to patients for one of three reasons:

Resuscitation fluid is given as therapy to achieve either an end-organ function (increased urine output, improved mentation) or hemodynamic improvement in a patient experiencing a systemic inflammatory response or shock state. Organ dysfunction or hemodynamic compromise in these patients is due to a loss of effective circulating volume. Resuscitation fluid is given to restore adequate volume, generally in bolus increments, guided by clinical endpoints, although certain specific conditions, such as rhabdomyolysis and crush injuries, are resuscitated with high-rate continuous infusions.

Replacement fluid is used to correct water and electrolyte deficits due to pathologic volume loss. Examples include plasma loss in burns, watery diarrhea in GI illness, and diabetes insipidus in head trauma. Replacement fluid is generally given as a continuous intravascular, enteral, or per rectum (PR) infusion, or by strictly scheduled PO intake. These patients may not be in a systemic inflammatory or shock state, but are at risk of deteriorating into these states if their fluid losses are not replaced.

Maintenance fluid is given as nutrition to provide water and electrolytes lost via ongoing physiologic sweat, respiratory, urine, and stool output, as well as glucose required chiefly for

brain metabolism. The body's absolute requirement for fluid is approximately 500mL/day to clear toxic solutes through the kidneys, and another 500mL/day to replace sweat losses. Febrile patients may lose an additional 100-150mL/day for every degree over 38C. Respiratory losses of approximately 500mL/day are generally offset by generation of water from oxidation, unless the patient is hyperventilating. Children are much more sensitive to fluid loss than adults due to larger insensible loss per kilogram, and decreased renal concentrating ability, so more thought needs to be put into the content and amount of maintenance fluid in children.

The route of fluid administration takes on additional importance in PFC due to resource limitations. For resuscitation and replacement, there is evidence that describes good outcomes with oral or enteral resuscitation of shock due to burns up to 40% TBSA, and dehydration from diarrheal illness. There are limited studies of successful resuscitation of hemorrhagic shock with fluids given per rectum. We recommend that a trial of oral or enteral resuscitation be considered for burns less than 40% TBSA, and hypovolemic shock due to dehydration, and that these routes be considered for hemorrhagic and septic shock if blood or IV fluids are unavailable. **Providers in the PFC environment should be trained in the preparation (glucose and electrolyte content) and administration of oral, enteral and PR fluids for resuscitation, replacement and maintenance requirements.**

The PFC WG also recommends that oral or enteral routes for maintenance fluids be encouraged in PFC in order to conserve resources.

Fluid given for resuscitation comprises only half of the therapy needed to manage the critically ill or injured patient. The other aspect of therapy is treatment of the underlying cause (e.g. hemostasis for hemorrhagic shock, antimicrobials for septic shock, etc.) It is beyond the scope of this paper to discuss the details of treating and resuscitating the various shock states, but an overview of fluids in PFC would be remiss if it did not remind the practitioner that resuscitation must be accompanied by treatment for the critically ill or injured patient to have the best chance of survival and recovery.

Colloids

Semisynthetic colloid solutions, such as Hetastarch, are made of large molecules that attract fluid into the intravascular space from the interstitium and rarely cross capillary membranes. Giving 500mL of Hetastarch to a patient will have the approximately equivalent effect of giving 2000 – 2500mL of Normal Saline, and the effect will last longer since only 20 – 25% of crystalloids remain in the intravascular space at one hour compared with nearly 100% of colloids (including blood). Thus, a medic can carry 500mL of Hetastarch, instead 1500mL of Normal Saline. This weight and cube advantage is the strongest argument for Starches (Colloids) over Crystalloids in initial resuscitation.

As the SOF medic transitions a PFC patient from the initial treatment and stabilization (“ruck” phase) to the “truck” or “house” phase, the weight advantage of Starches becomes less important. Starches, used in critically sick patients, can increase the incidence of kidney disease and worsen patient outcome. Because of these risks, they should be used for initial resuscitation or replacement fluids only. There is no role for their use as a maintenance fluid, since they contain none of the nutritional requirements (electrolyte and glucose) required.

In summary, the recommended use of semisynthetic colloids is as follows:

- Initial volume expansion in hemorrhagic shock while provision of blood is being arranged.
- Resuscitation of perfusion to dysfunctional organs or unstable hemodynamics in non-hemorrhagic shock states.
- Reducing crystalloid requirements in burn patients at risk for over-resuscitation, and peripheral or abdominal compartment syndromes.

Crystalloids

Fluids in this category include Normal Saline (NS), and buffered or “balanced” solutions such as Lactated Ringers (LR) and Plasma-Lyte A. These electrolyte solutions expand intravascular volume, however, only 20 – 25% of a volume of crystalloid infused remains in the intravascular space. Because of this, when given as resuscitation fluid to improve organ perfusion or hemodynamics, they should be given as large-volume boluses (500mL – 1L per bolus) that will demonstrate a physiologic effect on the organs and vascular system.

Crystalloids given as continuous infusions to critically ill patients are more likely to diffuse out of the intravascular space (“third-space”) than when given as boluses. For this reason, any continuous infusion in the critically ill or injured patient should be the minimum necessary to replace water and electrolytes lost through sweating and urine, unless they have a condition that specifically calls for large-volume continuous infusion therapy (e.g. burns, crush injuries, rhabdomyolysis). Complications of large-volume crystalloid resuscitation include: compartment syndromes, acute respiratory distress syndrome, and dilutional coagulopathy. In addition, normal saline can cause hyperchloremic acidosis in large-volume resuscitation.

Despite these cautions, crystalloids are not “the enemy.” They are first line therapy in expanding plasma volume in septic shock. Also, in the initial response to a hypotensive trauma patient, a careful provision of crystalloids remains first-line (along with hetastarch) to expand plasma volume, optimize organ perfusion, and reduce the risk of hypovolemic shock compounding the inflammatory response to tissue injury.

Differences between crystalloids

Normal saline (NS) is an unbalanced crystalloid with a supra-physiologic concentration of chloride, which can produce a hyperchloremic metabolic acidosis in larger infusions. Increasing evidence shows that this worsens inflammation and decreases kidney function. One advantage of NS is its compatibility with many IV medications and blood transfusions.

Lactated Ringers (LR) is a *slightly* hypotonic solution that has a minimal effect on pH. It is referred to as a “balanced” crystalloid due to presence of organic anion (lactate) and lower chloride. The lactate component was once thought to be harmful, especially in critically ill patients with lactic acidosis. Research found that the D-isomer of lactate was pro-inflammatory, but that L-isomer has beneficial immuno-modulatory properties. Lactate in LR currently used is the L-Lactate form. LR’s mild hypotonicity makes it a less ideal fluid for patients with cerebral edema, and in these cases, NS or Plasma-Lyte A would be recommended, if available.

Plasma-Lyte A Injection solution is a normotonic solution that can slightly raise a patient’s pH in larger infusions. Plasma-Lyte A is compatible with blood transfusions and with many IV medications. Plasma-Lyte A costs approximately 1.7 times more than NS, and is generally

considered equivalent to LR as a resuscitation and maintenance fluid, though it is less prevalent in the U.S. medical supply system.

Resuscitation goals of hemorrhagic shock patients in a PFC environment

Robust MEDEVAC infrastructure in OEF has afforded close adherence to the Golden Hour for damage control surgery. The permissive hypotension strategy for hemorrhagic shock patients with penetrating trauma to the chest and abdomen makes sense with 1-2 hour evacuation times from point of injury to damage control hemostasis. In a PFC situation, evacuation may be delayed for hours to days. Maintaining a patient in a hypotensive state beyond the Golden Hour puts the patient at risk for end organ injury, reperfusion injury, and a worsening shock state from compensated, to decompensated, to refractory. **Fresh whole blood (FWB)** is the fluid of choice for patients in hemorrhagic shock.

To mitigate these risks in the PFC environment, we recommend the provider aim for a “low-normal” perfusion state defined as *any one of* the following: MAP of 65mmHg, adequate urine output (0.5cc/kg/hr) or adequate mentation (though mentation will be preserved at the expense of all other systems and vital organs). Although this recommendation is greater than the MAPs of 40-60mmHg referenced in discussions of hypotensive resuscitation, 65mmHg is still a low-normal target that will minimize clot disruption and coagulopathy in hemorrhagic shock, while providing adequate tissue perfusion in all shock states.

Resuscitation goals are important because they prompt earlier provider responses, but beware of “chasing numbers” in patients who have normal mental status and adequate UOP. The goal of resuscitation is to treat the patient in front of you, not achieve a certain number. Patients may have adequate organ function and circulation below a MAP of 65mmHg.

This “low normal” resuscitation strategy is for patients in hemorrhagic shock only. Do not apply this strategy to patients with other etiologies of shock.

Recommended strategy for fluid therapy in PFC:

Goal: The selection of maintenance or resuscitation (bolus) fluid should be guided by the patient’s clinical condition: if UNSTABLE with inadequate intravascular volume, resuscitate with bolus fluid. If STABLE with adequate intravascular volume, use maintenance fluid. A general target is to achieve a urine output of 0.5mL/kg/hour. Goals of UOP up to 1mL/kg/hour may be advised by telemedicine consultation for specific conditions such as significant crush injury.

Accurate measurement of urine output will most likely require Foley catheterization in critically ill patients. In complex cases such as burns, we recommend dumping the urine from the collection bag into a specimen cup or other receptacle every 60 minutes to accurately measure the hourly output. Simply estimating UOP in a large Foley collection bag may not be precise enough, since the difference of 10mL may indicate an increase or decrease in your fluid rate. Trends of urine output over time are important to properly manage, and will help communicate the precise status of your patient to higher medical authority via Telemedicine/specialist consultation.

Maintenance: We recommend Lactated Ringers (LR) or another balanced solution, such as Plasma-Lyte A, for maintenance fluid requirements. For adults, we recommend starting at a total daily replacement volume of 1.2L (50mL/hour). For inadequate urine output lasting more than two hours, bolus 250 – 500mL of crystalloid, and increase the rate by 25%.

For children, we recommend the “4-2-1” formula to derive the initial hourly maintenance fluid rate, based on the patient’s body weight.

4mL/kg for the first 10kg
plus 2mL/kg for the next 10kg
plus 1mL/kg for the remainder of the patient’s weight.

The total is the hourly maintenance fluid rate.

Example: 40 kg child.

$(4\text{mL/kg} \times 10\text{kg} = 40\text{mL}) + (2\text{mL/kg} \times 10\text{kg} = 20\text{mL}) + (1\text{mL/kg} \times 20\text{kg} = 20\text{mL})$
 $40\text{mL} + 20\text{mL} + 20\text{mL} = 80\text{mL/hour}$ is the patient’s maintenance requirement

Specific scenarios: These cases, in particular, REQUIRE early call for telemedicine.

BURNS

-If a patient has large burns (>20% second degree Total Burn Surface Area [%TBSA] or >10% third degree; or burns of critical areas: head, hands, feet, genitalia), early telemedicine consultation is critical.

-The %TBSA will drive your fluid resuscitation approach. In general:

1. **<15% TBSA:** non-aggressive fluid resuscitation recommended, PO hydration may be sufficient
2. **15-40% TBSA:** this is the patient population in PFC that requires our diligent management, and is likely to reduce morbidity with proper resuscitation and attention
3. **>40% TBSA:** this will require major resuscitation, likely airway management with cricothyrotomy or endotracheal intubation, and has an ominous prognosis

-Burns require large amounts of resuscitation fluids. For this reason, LR or Plasma-Lyte A are recommended over Normal Saline. A recommended formula to estimate fluid requirements is below:

The Rule of Tens (for burns): $10\text{mL/hr} \times \%TBSA$

-If your patient weighs 40-80kg, multiply the %TBSA x 10 to get the hourly infusion rate

-If your patient weighs >80kg, add 100mL/hour for each 10kg over 80kg

-Example: A 100kg patient with 40%TBSA burn

(For the first 80kg) $40\% \text{ TBSA} \times 10 = 400\text{mL/hour}$, plus

(For the remaining 20kg) $100\text{mL} \times 2 = 200\text{mL/hour}$

$400\text{mL} + 200\text{mL} = 600\text{mL/hour}$ infusion rate of LR or Plasma-Lyte A

-If UOP <30mL/hr, increase the hourly fluid rate by 20% for the next hour and reassess

-If UOP >50mL/hr, decrease the hourly fluid rate by 20% for the next hour and reassess

-Both over- and under-fluid resuscitation can cause significant complications in burn patients (most importantly hypovolemic shock in the former, compartment syndromes in the latter).

The key part of burn management is the need to monitor urine output and be **as ready to decrease fluid rate for supra-therapeutic urine output as to increase it for suboptimal output**. One of the causes of “fluid creep” that can lead to compartment syndromes may be that providers are less likely to decrease infusion rates when UOP is above goal, than they are to increase rates when UOP is below goal.

Colloid infusion, either hetastarch or albumin, has been shown to reduce fluid requirements in burns, as well as decrease the incidence of abdominal compartment syndrome. One approach is to change to a colloid infusion for patients whose 24-hour crystalloid requirements exceed 6mL/kg/%TBSA.

Finally, oral or enteral nutrition has been studied in burn areas up to 40%. Though not a primary solution, this technique could be very useful in a resource-limited PFC environment.

SEPSIS

-Though the recognition of sepsis may be difficult, especially early in the disease process, clinically a patient should be considered septic if they have an infection (fever and/or clinical concern such as cough productive of purulent sputum, diarrhea, skin infection or signs of systemic infection such as rigors) accompanied by an elevated heart rate and/or respiratory rate. They are considered to be in septic shock if they have decreased blood pressure, not responsive to initial volume resuscitation (1-2L fluid bolus).

-There is a large fluid requirement due to capillary leak. Initial resuscitation (2-4L) can be attempted with NS, but recommend change fluids to LR or Plasma-Lyte A if much more is required.

-Titrate total fluids to maintain systolic BP >90 (ideally goal of MAP >65), and adequate UOP (0.5mL/kg/hr)

-Initiate broad-spectrum antibiotic coverage (and source control-if applicable) early.

- A good starting point is 2L bolus initially, then 500mL boluses until SBP>90 (MAP greater than >65). You may have to re-bolus frequently while also considering maintenance fluid needs if the patient is unable to take oral fluids or nutrition.

HEAD INJURY

-3% (hypertonic) Saline solution – HTS - for signs of significant elevated intra-cranial pressure (ICP):

-Progressively worsening mental status (decreased GCS score) or other signs such as bradycardia, widening pulse pressure, increased diameter of optic nerve sheath seen on ultrasound, in known head-injured patient with adequate blood pressure and UOP. (Remember, lowered blood pressure can lead to decreased mental status without head injury).

If giving HTS, a maintenance fluid is likely not necessary. Since nearly 100% of 3% saline remains in the intravascular space; 250mL is equivalent to over 1 liter of crystalloid.

-LR, Plasma-Lyte A or oral replacement for patients with head injury and no signs of elevated ICP.

Strategy for Hypertonic Saline administration:

250mL bolus of 3% followed by 50mL/hr basal rate for an average 80kg patient. This is APPROXIMATE and ideally, you can measure serum sodium (Na) with Point-Of-Care lab Testing (POCT; e.g. *i-Stat*).

Detailed strategy (if you have POCT available):

1. Give 250mL 3% saline (HTS) bolus IV (children 5mL/kg) over 10–15 minutes.
2. Follow bolus with infusion of 3% HTS at 50mL/hour (children 1mL/hour).
3. If awaiting transport; check serum sodium (Na) levels every hour:
 - a. If Na < 150 mEq/L, re-bolus 150mL over 1 hour, then resume previous rate
 - b. If Na = 150–154, increase 3% HTS infusion by 10mL/hr
 - c. If Na = 155–160, continue infusion at current rate
 - d. If Na > 160, hold infusion, then recheck in 1 hour
4. Once Na is within the goal range (155-160), continue to follow the serum Na level every 6 hours.
5. After cessation of 3% HTS infusion, continue to monitor serum Na for 48 hours to monitor for rebound hyponatremia.

Logistics: (The BOTTOM LINE on what to pack)

Basic recommendations for deployment:

- 3-4 Fresh Whole Blood transfusion kits
- 3-4 500mL bags of Hextend (if used as initial resuscitation per TCCC guidelines)
- 1 case Normal Saline, or the equivalent, with 6-8 250mL NS bags, and the balance being 1L bags
- 2-3 cases LR or Plasma-Lyte A to use for large resuscitations
- 6-8 bags (250 or 500mL) of hypertonic (3%) saline (HTS)
- 10-15 micro-drip administration tubing sets (need for maintenance AND sedation drips)

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