Optimal Fluid Resuscitation in Pediatric Sepsis

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Introduction

Sepsis is a life-threatening illness that has been around for centuries but continues to affect millions of people worldwide. One of the first and most imperative effects that is addressed in septic patients is the hypovolemia that ensues from immense vasodilation. Hypovolemia, next to cardiomyopathy, is the main source for the hemodynamic instability seen in sepsis patients (Yoon, 2012). This hemodynamic instability will eventually lead to multi-organ system failure and death. For many years sepsis treatment was approached in the same manner in both children and adults due to insufficient or poor research into pediatric sepsis (Kawasaki, 2017). However, as time has progressed, many physicians have questioned if there is a better approach to treating children. The starting point in creating improved pediatric treatment is the most pressing issue, initial fluid resuscitation. Pediatric patients are more likely to lose fluids rapidly due to their proportionally higher ECF:ICF volume ratio. This ratio predisposes young patients to increased volume loss and therefore increases their chances of hypovolemic shock (Wheeler, 2011). The debate between whether to initially use colloids or crystalloids each have their own advantages and disadvantages with physician support on both sides.

Colloids, such as 5% albumin and hydroxyethyl starch, have a multitude of benefits, especially for a hemodynamically unstable septic patient. Colloids are seen to increase extracellular fluid two to three times more than what was administered, therefore less fluid needs to be given to quickly reach hemodynamic stability. Another study directly compared the extracellular fluid volume (ECFV) differences after administering 5% albumin and normal saline, in which it was found that after infusion of normal saline the ECFV increased proportionally to the amount administered and the PV to ISFV ratio was 1:3. After infusion of 5% albumin the ECFV increased by double and the PV and ISFV amounts increased equally (Ernest, 1999). However, colloids have been seen to cause metabolic acidosis, increased blood viscosity, and are more expensive for the patient (Khandelwal, 2002). Not only that, but an independent study focused on the blood rheology effects of crystalloids and colloids, specifically albumin, hydroxyethyl starch, and normal saline. The results found that there was increased erythrocyte aggregation and increased blood viscosity in the blood mixed with hydroxyethyl starch and albumin compared to the mixtures with normal saline (Castro, 1997).

Crystalloids such as normal saline and lactated ringers are some of the most common fluids used in not only sepsis treatment, but in the hospital daily. Due to the wide availability of crystalloids, significantly cheaper cost, and almost no demonstration of injury they are often the go-to fluid choice (Ngo, 2001). However, normal saline has been seen to cause metabolic acidosis in the patients who received infusions (Stefan, 1999). In addition to that, although lactated ringers hasn't been seen to produce acidosis, when used for initial fluid resuscitation it preformed significantly worse than all other fluid types and was associated with a much longer hospital recovery.

Although both crystalloids and colloids offer their own unique advantages and disadvantages this study aims to measure the deleterious effects and subsequent outcomes in both colloid and crystalloid administration in pediatric sepsis. Specifically, we aim to answer, what is the best fluid to use for initial fluid resuscitation in pediatric sepsis between normal saline, lactated ringers, 5% albumin, and hydroxyethyl starch? It was anticipated that the septic pediatric patients in the colloid's groups would reach hemodynamic stability, and ultimately full recovery, much quicker than the crystalloid group despite the possible adverse effects associated with colloid administration.

Method

Participants

Participants consisted of 100 critically ill pediatric sepsis patients in the Pediatric Emergency and Intensive Care Unit. All patients were between the ages of 5 to 12 years old and had no underlying organ failure or immune deficiencies. The origination of sepsis the patients presented with was not considered as an exclusion factor.

Materials

Initial fluid resuscitation was carried out with either crystalloid or colloid, two for each respective category. For crystalloids, 0.9% normal saline and lactated ringers were used, while for colloids, 5% albumin and hydroxyethyl starch were administered. In order to measure the hemodynamic parameters both invasive and non-invasive monitors, specifically a central line and a blood pressure cuff, were used, respectively. Additionally, a viscometer and centrifuge were used in order to measure plasma viscosity and erythrocyte aggregation.

Procedure

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Twenty-five patients were randomly assigned to four different groups: Group 1 (0.9% normal saline), Group 2 (lactated ringers), Group 3 (5% albumin), and Group 4 (hydroxyethyl starch). Twenty-five random numbers, 1-100, were assigned to each group and the pediatric patients who participated in the study were also given a random number. Once the study started, these patients were then allocated to their respective group per their number assignment. Randomized controlled trials were conducted on all four groups of patients and all patients received initial fluid resuscitation with the fluid for their respective group. Fluid boluses were administered at 110mL/kg for crystalloids and 70mL/kg for colloids every 15 minutes until hemodynamic stability was reached as determined by the patient's clinician or if the CVP surpassed 10mmHg. If hypotension persisted or there was poor perfusion after the fluid boluses were administered, then vasopressors were used. Dopamine was the first vasopressor preferred, moving onto epinephrine if dopamine failed to stabilize the patient. Hemodynamic parameters were measured before in order to establish a baseline, during resuscitation every hour, and after fluid resuscitation for up to 24 hours. The specific parameters measured were heart rate, blood pressure, respiratory rate, ECFV, plasma viscosity, and erythrocyte aggregation. In addition to the hemodynamic and rheologic parameters measured, ABG's and CMP's were drawn every three hours in order to monitor the patient's pH and electrolytes. Hemodynamics were measured with invasive measures, a central line, and non-invasive measures, a blood pressure cuff, on opposite sides of the patient's body. These parameters were measured until the patient was considered fully recovered by their physician. The rheological parameters were measured using a viscometer and centrifuges during and after resuscitation. Lastly, the ECFV was measured by adding 2mL/kg of a solution containing Evans blue, tritiated water, and sucrose at the end of each fluid bolus. Blood samples were taken from the patient at 20-minute intervals for up to three hours. The ECFV was estimated on the blood samples taken using the Zweens and Frankena method.

Figure 1. 0.9% Normal saline

Figure 2. Lactated Ringers

Figure 3. 5% Albumin

Figure 4. Hydroxyethyl Starch

Results & Discussion

Patients in Group 1 (0.9% normal saline) are anticipated to present with similar hemodynamic recovery times in relation to Group 3 (5% albumin) and Group 4 (hydroxyethyl starch). Additionally, a decreased erythrocyte aggregation, decreased plasma viscosity, a slight decrease in pH levels, however not significant enough to require treatment, and increased ECFV in a 1:1 ratio is expected. Patients in Group 2 (lactated ringers) are anticipated to have similar hemodynamic time results to Group 1, however it is expected that no acidosis will be seen and a significant increase in overall recovery time will be present. The ECFV changes are projected to be similar to those seen in Group 1 and rheological changes should also be similar to that of Group 3 and Group 4. Patients in Group 3 are estimated to perform incredibly well, showing a quicker recovery time to hemodynamic stability and an increased ECFV in a 1:2 ratio. However, 5% albumin has been seen to show increased erythrocyte aggregation and increased plasma viscosity. It is also anticipated that no pH changes will be seen that are significant enough for treatment. Lastly, Group 4 is also anticipated to perform well, showing a shorter hemodynamic recovery time and an increased ECFV in relation to the amount administered. In a similar fashion to patients in Group 3, there will be an increase in erythrocyte aggregation and plasma viscosity. However, patients in Group 4 will show the largest increase in the rheological parameters measured in comparison to the other groups. Once again, no pH changes are expected to be significant enough for treatment. In summary, there is no cure for this sepsis and urgent treatment is key to obtaining the best possible patient outcome. While there are multiple crucial factors in immediate treatment, initial fluid resuscitation used is a fundamental factor in said outcome. It was expected that the pediatric patients administered the colloids, Group 3 and Group 4, would recover more quickly due to the increased ECVF volume with less colloid administered, therefore reaching hemodynamic stability faster. However, these patients have also been seen to have increased clotting which could lead to more issues. The evidence to be presented will allow for proper fluid management choices for optimal fluid resuscitation between 0.9% normal saline, lactated ringers, 5% albumin, and hydroxyethyl starch. Some limitations of this study include population size and sepsis type. Many parents are against experimental testing of any kind on their children, therefore more studies would need to be conducted on larger samples sizes in order to say with determination that colloids are the best fluid choice. Not only that, but there are many different originations for sepsis leading to septic shock. More studies would need to be conducted on all types of sepsis in order to ensure coverage over all sepsis infections no matter the origination.

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