Article

Effects of administration of a synthetic low molecular weight/low molar substitution hydroxyethyl starch solution in healthy neonatal foals

Kate L. Hepworth-Warren, David M. Wong, Bonnie L. Hay-Kraus, Chong Wang, Yaxuan Sun

Abstract — This study compared the effects of IV administration of isotonic fluid therapy and colloidal fluid therapy in healthy neonatal foals. Fifteen healthy neonatal foals were used in a randomized blinded prospective clinical study. Foals were randomly assigned to receive a bolus of 20 mL/kg of tetrastarch (TES) or balanced crystalloid solution. Vital parameters, colloid osmotic pressure (COP), and various clinicopathologic variables were assessed prior to infusion and at various time points up to 120 h after infusion. The treatment group (TES) had a significant increase in both COP and percentage increase in COP at 1 and 3 h. The COP was significantly lower than baseline at 3 h in the control group. No significant changes were observed in coagulation parameters in either group. Tetrastarch was effective in increasing COP for 3 h after infusion and had no notable adverse clinical effects in this group of healthy foals. Further studies are warranted regarding optimal dosing and effects in clinically ill foals.

Résumé — Effets de l'administration d'une solution de substitution synthétique d'amidon hydroxyéthylé de faible poids moléculaire/faible molarité chez des poulains néonataux en santé. Cette étude a comparé les effets de l'administration IV d'une fluidothérapie isotonique et d'une fluidothérapie colloïdale chez des poulains néonataux en santé. Quinze poulains néonataux ont été utilisés dans une étude clinique prospective randomisée. Les poulains ont été assignés au hasard pour recevoir un bolus de 20 mL/kg de tétra-amidon (TEA) ou d'une solution cristalloïde équilibrée. Les paramètres vitaux, la pression osmotique colloïdale (POC) et diverses variables clinicopathologiques ont été évalués avant l'infusion et à divers moments jusqu'à 120 heures après l'infusion. Le groupe de traitement (TEA) a subi une hausse importante de la POC et une augmentation du pourcentage de POC à 1 et 3 heures dans le groupe témoin. Aucun changement significatif n'a été observé dans les paramètres de coagulation des deux groupes. Le tétra-amidon a été efficace pour l'augmentation de la POC pendant 3 heures après l'infusion et il n'a pas eu d'effets cliniques négatifs notables dans ce groupe de poulains en santé. De nouvelles études sont justifiées concernant le dosage optimal et les effets chez les poulains cliniquement malades.

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Department of Veterinary Clinical Sciences (Hepworth-Warren, Wong, Hay-Kraus) and Veterinary Diagnostic and Production Medicine (Wang, Sun), College of Veterinary Medicine, Iowa State University, Ames, Iowa, USA.

Address all correspondence to Dr. Kate Hepworth-Warren; e-mail: katelhepworth@gmail.com

This study was performed at the Lloyd Veterinary Medical Center at Iowa State University (ISU). All laboratory analyses were performed at the clinical pathology laboratory at ISU with the exception of measurement of Factor VIII: C activity and vWF antigen, which were measured at the Cornell University Animal Health Diagnostic Center Comparative Coagulation Laboratory.

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Introduction

Fluid therapy is a key component of equine neonatal critical care, but minimal data are available describing the benefits and disadvantages of using crystalloids *versus* colloids in these patients. Crystalloids, such as Plasmalyte (Abbott Animal Health, Chicago, Illinois, USA) or Normosol (Hospira, Lake Forest, Illinois, USA), are attractive resuscitative fluids as they are readily available and inexpensive. However, rapid infusion of large volumes of crystalloid solutions can decrease intravascular colloid osmotic pressure (COP), resulting in interstitial edema (1,2). In comparison, colloid solutions contain higher molecular weight molecules that cross the intact vascular endothelial barrier less readily and therefore exert a more prolonged volume expansion by increasing COP and remaining within the intravascular space for a longer period of time (2–4).

The use of synthetic colloid solutions is controversial, however, as they have been associated with coagulopathies and acute kidney injury in humans (5). The mechanism by which synthetic colloids induce coagulopathy involves dilution of and interference with clotting factors, fibrinolysis, and platelet function (6,7). In addition, accumulation of colloid molecules within renal tubular cells as well as an increased COP has the potential to produce kidney dysfunction or acute renal failure (8,9). Reduced concentrations of von Willebrand factor (vWF) and Factor VIII as well as prolongation of prothrombin time (PT) and activated partial thromboplastin time (aPTT) have been documented in horses administered 10 mL/kg body weight (BW) of 6% hetastarch (HES, 600/0.75) (7,10–12). These aforementioned negative side effects are dose-related and are more common with colloid solutions that have a higher molecular weight and molar substitution ratios (13–16). Recently, a novel tetrastarch (TES) solution with lower molecular weight and molar substitution ratio (Vetstarch®; 130/0.4 in 0.9% sodium chloride; Abbott Animal Health) has become commercially available for veterinary use and has less adverse effects in horses, humans, and sheep compared with synthetic colloid solutions that have higher molecular weights and molar substitution ratios (8,13,17–19).

A study in adult horses documented more effective volume expansion and arterial blood pressure support as well as a more sustained effect on COP with the use of TES compared to 0.9% NaCl (8). In addition, a shorter duration of adverse effects on platelet function was noted with TES, compared with HES (8). Furthermore, an *in vitro* study using equine blood suggested less impairment of coagulation when low molecular weight/low molar substitution solutions were used (7). While the safety and efficacy of a novel TES solution has been evaluated in adult horses (8,19), safety and impact of administration of synthetic colloid solutions, in particular low molecular weight/low molar substitution solutions, have not been evaluated in foals.

The objectives of this study were to use various physical examination and coagulation parameters as well as COP to compare the effects of a synthetic, low molecular weight/low molar substitution colloid solution with those of a crystalloid solution administered to healthy neonatal foals. We hypothesized that administration of low molecular weight/low molar substitution colloid solution would have minimal side effects in healthy neonatal foals while increasing COP.

Materials and methods

Animals

Fifteen clinically healthy neonatal Thoroughbred and Quarter horse foals owned by the Iowa State University (ISU) Department of Animal Sciences with a mean age of 4 d (range: 3 to 5 d) were included in the study. There were 5 colts and 10 fillies with a mean weight of 57.9 kg (range: 49.1 to 68.2 kg). Foals were deemed healthy based on physical examination and adequate passive transfer of maternal antibodies measured at 24 h of age. A random number generator was used to assign each foal to either the treatment or control group. All procedures were approved by the ISU Institutional Animal Care and Use Committee (12-12-7474-E).

Instrumentation and fluid administration

A 14-gauge, 13 cm over the wire polyurethane IV catheter (Milacath; Mila International, Erlanger, Kentucky, USA) was placed in the jugular vein to allow for blood collection and administration of either a synthetic colloid (TES) or crystalloid (Plasmalyte). The control group was administered 20 mL/kg BW of crystalloid solution (Plasmalyte) over 15 min using a high volume fluid pump (FloStar Infusion Pump; Anesthesia Safety Products, Woburn, Massachusetts, USA) while the treatment group was administered 20 mL/kg BW of TES over 15 min. The dose of 20 mL/kg of TES was the dose recommended by the manufacturer; this is a common bolus dose of crystalloids used in neonatal foals for resuscitation (20).

Blood (12 mL) was collected from the IV catheter at times −0.5, 0, 0.5, 1, 1.5, 2, 3, 6, 12, and 24 h with the start of the fluid infusion designated as time 0. Samples were collected by jugular venipuncture at 48, 72, 96, and 120 h. Urine was obtained via free catch at 0 and 24 h for evaluation of kidney function. Samples were collected, submitted for analysis, and data organized by "blinded" investigators; administration was facilitated by a "non-blinded" technician. All blood samples were immediately placed in EDTA, citrate, or clot tubes. Packed cell volume (PCV), total solids (TS), and lactate were determined immediately, while the remaining serum or plasma was harvested and stored at −80°C. Physical examination parameters including heart rate, respiratory rate, and rectal temperature were recorded at each sampling time.

Assays

Blood lactate was measured with a previously validated point-of-care device (Lactate Pro, Arkray, Kyoto, Japan). Packed cell volume and TS were measured immediately after collection at all aforementioned time points. Colloid oncotic pressure (COP) was measured from serum at times 0, 1, 3, 6, 12, 24, 48, 72, 96, and 120 h (Wescor 4420 Colloid Osmometer; Wescor, Logan, Utah, USA). To evaluate the effects of TES on serum electrolytes the serum sodium, chloride, potassium, and bicarbonate were measured along with anion gap (Ortho Vitros 5.1; Johnson & Johnson, Rochester, New York, USA) at times 0, 1, and 24 h; PT and aPTT (ACL Elite; Instrumentation Laboratories,

Table 1. Changes in colloid osmotic pressure (COP) over time

	COP (mmHg)		COP (mmHg) % Change from baseline (T = 0 h)	
Time (h)	Treatment	Control	Treatment	Control
0	14.6 ± 1.2	16.1 ± 3.3		
1	17.2 ± 1.4[a]	15.6 ± 2.8	18.0 ± 4.3[a,b]	−1.3 ± 21.5[b]
3	16.5 ± 1.2[a]	15.9 ± 2.9	13.8 ± 3.7[a,b]	2.0 ± 18.2[a,b]
6	16.1 ± 1.2	15.9 ± 2.1	10.9 ± 3.6[a]	1.9 ± 22.2
12	15.5 ± 1.2	16.0 ± 3.4	6.8 ± 3.8	0.4 ± 18.6
24	15.0 ± 1.3	16.0 ± 3.1	3.2 ± 6.5	0.8 ± 19.3
48	15.3 ± 1.5	16.5 ± 2.6	4.8 ± 4.1	4.8 ± 17.1
72	15.4 ± 1.3	16.4 ± 2.1	5.8 ± 8.0	4.8 ± 20.7
96	15.9 ± 1.5	17.2 ± 1.2	9.6 ± 11.2[a]	10.5 ± 20.5[a]
120	16.3 ± 1.1	17.6 ± 2.4	11.3 ± 6.6[a]	10.9 ± 12.9[a]

[a] Indicates significance from baseline within group.
[b] Indicates significance between groups.
$P < 0.05$.

Bedford, Massachusetts, USA), and CBC parameters (including platelet count and fibrinogen) (Advia 120; Siemens, Malvern, Pennsylvania, USA) were measured at times 0 and 24 h. Urine was analyzed at 0 and 24 h for gammaglutamyl transferase (GGT) activity, creatinine concentration, GGT: creatinine (Ortho Vitros 5.1), and routine urinalysis. Citrated plasma from 0 and 24 h was frozen at −80°C until completion of study and a subset of samples (2 samples from 6 foals in each group) were analyzed at the Cornell University Animal Health Diagnostic Center Comparative Coagulation Lab for Factor VIII: C activity and vWF antigen.

Statistics

Statistical analysis was performed using statistical software (SAS; SAS Institute, Cary, North Carolina, USA). Sample mean and standard deviation for the control and treatment groups were calculated for each variable at each time point. Quantitative variables [PT, aPTT, WBC, lymphocytes, monocytes, plasma protein, fibrinogen, sodium, potassium, chloride, anion gap, COP, PCV, TS, temperature, heart rate and respiration, urine GGT: creatinine ratio, neutrophil, RBC, platelets, urine specific gravity (USG), and bicarbonate] were analyzed using repeated measure analysis of variance (ANOVA) models with time, group, and the interaction between time and group as fixed effects and animal as subject of repeated measures. Residual plots and normal probability plots were used to ensure the assumption of normality was reasonable. Differences between groups at each time point were assessed and tested for significance. Differences between baseline time (time = 0) and all the other time points were also compared for each of the treatment and control groups. Additionally for COP, PCV and TP, the differences for percent change from baseline time and all other time points were also compared for the treatment and control groups. Lactate was often below the lower limit of detection and reported as "low;" therefore, this variable was analyzed by rank. Differences between time points were assessed by Friedman's test for each of the treatment and control groups. Differences between groups at each time were assessed using Wilcoxon's rank sum test. In all the statistical analysis, the significance level was set at 0.05.

Results

Colloid oncotic pressure

Nine foals received TES (treatment group) and 6 foals received crystalloid (Plasmalyte®) solution (control group). Changes in COP are shown in Table 1. The treatment group had a significant increase in COP from baseline at 1 and 3 h and a significant percentage increase from baseline at 1, 3, 6, 96, and 120 h. A significant percent change from baseline was present at 3, 96, and 120 h in the control group. The treatment group had a significantly higher percentage increase from baseline at 1 and 3 h compared to the control group.

Packed cell volume and total solids

Changes in PCV and TS are listed in Table 2. In the treatment group, PCV (%) was significantly decreased from baseline at 0.5, 1, and 2 h post-infusion and there was a significant percentage decrease in PCV at 0.5, 1, 1.5, 2, 3, and 72 h. There was no significant difference in PCV (%) or percentage change from baseline in the control group. There were no significant differences in PCV (%) between the treatment and control groups at any time. However, a significant difference in percent change from baseline was identified between the treatment and control groups at 0.5, 1, 2, 3, 6, and 12 h. There was no significant difference in TS, between the treatment group and baseline. However, TS in the control group had a significant change from baseline at 0.5 and 96 h. There was a significant difference in TS between treatment and control groups at 120 h. A significant percentage change in TS from baseline was identified in the treatment group at 48, 72, 96, and 120 h; the control group had a significant percentage change in TS from baseline at 72, 96, and 120 h. No significant difference in percentage change from baseline was identified between the treatment and control groups.

Coagulation parameters

The mean ± standard deviation values for fibrinogen, platelet count, PT, aPTT, Factor VIII: C and vWF:Ag activity are presented in Table 3. Fibrinogen was significantly lower in the

Table 2. Changes in PCV and total solids over time

	PCV (%)		PCV % change from baseline (T = 0 h)		Total solids (g/dL)		Total solids % change from baseline (T = 0 h)	
Time (h)	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control
0	37.7 ± 3.7	37.2 ± 3.3			5.4 ± 0.5	5.8 ± 0.4		
0.5	31.9 ± 4.1[a]	35.0 ± 3.0	−15.4 ± 5.6[a,b]	−5.7 ± 6.3[b]	5.3 ± 0.4	5.4 ± 0.2[a]	−2.2 ± 7.8	−6.7 ± 4.5
1	32.6 ± 4.1[a]	37.2 ± 3.8	−13.4 ± 8.6[a,b]	0.0 ± 6.0[b]	5.4 ± 0.4	5.5 ± 0.4	−0.3 ± 6.9	−3.6 ± 4.0
1.5	34.7 ± 4.9	37.7 ± 3.5	−7.9 ± 9.8[a]	1.4 ± 5.7	5.4 ± 0.4	5.5 ± 0.4	−0.6 ± 7.0	−4.3 ± 4.2
2	33.7 ± 4.7[a]	37.7 ± 2.7	−10.6 ± 9.0[a,b]	1.6 ± 7.0[b]	5.4 ± 0.3	5.5 ± 0.4	−0.6 ± 7.0	−3.7 ± 3.1
3	34.4 ± 4.7	38.2 ± 4.2	−8.6 ± 8.1[a,b]	2.6 ± 6.1[b]	5.5 ± 0.4	5.7 ± 0.4	0.9 ± 7.2	−0.7 ± 4.4
6	36.9 ± 5.4	39.3 ± 4.2	−2.0 ± 5.9[b]	5.7 ± 4.2[b]	5.4 ± 0.4	5.7 ± 0.3	−2.2 ± 2.7	−0.7 ± 3.6
12	36.4 ± 5.4	40.0 ± 4.2	−3.3 ± 10.0[b]	6.7 ± 6.9[b]	5.6 ± 0.4	5.6 ± 0.4	3.8 ± 8.7	−1.9 ± 4.8
24	36.9 ± 4.9	38.8 ± 5.0	−1.8 ± 6.0	4.3 ± 7.0	5.5 ± 0.4	5.8 ± 0.5	−0.4 ± 2.6	0.9 ± 4.3
48	37.1 ± 7.5	39.0 ± 2.5	−2.1 ± 12.6	5.3 ± 6.6	5.7 ± 0.5	5.9 ± 0.4	5.6 ± 10.5[a]	2.2 ± 4.9
72	35.4 ± 6.5	36.8 ± 5.9	−6.2 ± 11.3[a]	−1.1 ± 11.6	5.7 ± 0.5	6.1 ± 0.4	5.8 ± 10.2[a]	5.8 ± 7.1[a]
96	36.1 ± 5.3	37.5 ± 7.2	−4.3 ± 8.6	0.7 ± 16.0	5.7 ± 0.4	6.1 ± 0.4[a]	6.0 ± 8.4[a]	6.9 ± 6.7[a]
120	38.1 ± 6.8	34.8 ± 6.0	−1.4 ± 15.3	−6.5 ± 12.0	5.7 ± 0.5[b]	6.2 ± 0.6[a,b]	6.5 ± 9.5[a]	7.2 ± 6.3[a]

[a] Indicates significance from baseline within group.
[b] Indicates significance between groups.
$P < 0.05$.

Table 3. Coagulation parameters over time

	Treatment		Control	
	0 h	24 h	0 h	24 h
Fibrinogen (μmol/L)	8.49 ± 1.08	7.53 ± 1.08[a]	9.31 ± 1.33	11.76 ± 1.33[a]
PT (s)	16.1 ± 0.6	16.1 ± 0.6	17.1 ± 0.7	17.6 ± 0.7
PTT (s)	66.0 ± 4.0	63.5 ± 3.8	71.3 ± 4.6	64.1 ± 4.6
Platelet count ($\times 10^3$ cells/μL)	159.8 ± 65.0	147.3 ± 36.0	143.2 ± 35.7	116.3 ± 40.0
Factor VIII:C (%)	105.3 ± 57.4	109.8 ± 31.2	135.2 ± 55.8	119.7 ± 55.1
vWF:Ag (%)	140.8 ± 41.1	123.2 ± 83.1	131.0 ± 9.3	91.7 ± 43.1

[a] Indicates significance between groups.
$P < 0.05$.

treatment group when compared to the control group at 24 h. There were no other significant changes in these coagulation parameters at 0 and 24 h within or between groups.

Vital parameters, CBC parameters, electrolytes, urinalysis

No significant changes were identified within or between groups in regard to temperature, pulse, respiratory rate, lactate, WBC, lymphocytes, monocytes, or neutrophils between 0 and 24 h. Mean RBC was significantly lower at 24 h ($8.93 \pm 0.33 \times 10^6/\mu L$) compared to baseline ($9.26 \pm 0.33 \times 10^6/\mu L$) in the treatment group. Table 4 shows changes in electrolytes over time. Sodium was significantly higher in the treatment group compared to control at 24 h; however, all values were within the normal range.

Chloride was also significantly increased from baseline at 1 h in the treatment group but was not significantly different from control. No significant differences were identified in potassium, bicarbonate, anion gap, urine GGT: creatinine, or USG over time in either group.

Discussion

The benefits of using a synthetic colloid with a lower molecular weight and lower molar substitution for fluid therapy include decreased accumulation in the vasculature, fewer adverse effects on coagulation, and decreased renal damage (7,10,13,18). The findings in this report suggest that a bolus dose of 20 mL/kg BW of a novel TES solution in 0.9% NaCl increases oncotic pressure in healthy neonatal foals with no side effects. A significant increase in COP from baseline was identified at 1 and 3 h post-infusion of TES, whereas an equivalent dose of a balanced crystalloid solution caused a significant percentage decrease in COP from baseline at 3 h post-infusion. No significant changes were identified in clotting times, coagulation factors, platelet counts, fibrinogen, or urinary indices as an effect of administration of TES, indicating that the purported benefits of TES in humans and adult horses also apply to healthy neonatal foals.

Plasma clearance of synthetic colloids is dependent on the molecular weight and molar substitution of the solution, and is increased in solutions wherein these values are decreased (7,10,18,20). While increased plasma clearance leads to shorter duration of effect and a requirement for increased dosing frequency, this disadvantage is outweighed by the benefit of reduced tissue accumulation (16,20). While the literature does not identify specific incidences of adverse events associated with tissue accumulation in horses, it is reasonable to extrapolate from reports in human medicine and presume that they can occur. The most commonly reported complication from HES use in humans includes accumulation of colloid molecules in the kidneys and in the skin, the latter leading to intense pruritus (16,20,21). While the effect on COP may be relatively short, HES deposits in the skin and kidneys in humans have been

Table 4. Changes in electrolytes over time

	Sodium (mEq/L)		Chloride (mEq/L)		Potassium (mEq/L)		Bicarbonate (mEq/L)	
Time (h)	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control
0	134.6 ± 2.1	132.7 ± 2.7	97.2 ± 1.7	98.3 ± 1.8	4.1 ± 0.3	4.1 ± 0.2	32.8 ± 2.7	31.3 ± 1.9
1	135.2 ± 2.4	134.2 ± 2.7	100.8 ± 2.0[b]	99.2 ± 2.1	4.0 ± 0.2	4.1 ± 0.4	30.9 ± 4.3	29.7 ± 3.1
24	135.1 ± 3.0[a]	131.7 ± 2.9[a]	98.2 ± 1.9	98.3 ± 1.8	4.2 ± 0.3	4.1 ± 0.3	31.1 ± 4.3	29.3 ± 1.4

[a] Indicates significance between groups.
[b] Indicates significant change from baseline within group.
$P < 0.05$.

identified as long as 10 y after exposure to older HES solutions, illustrating the need for solutions with more rapid excretion (20). Older HES solutions exert an effect on COP for up to 120 h in healthy ponies at 10 and 20 mL/kg BW, IV, whereas the effect on COP of 10 mL/kg BW TES in adult horses has been documented to last from 8 to 24 h (10,12). The recommended dose of HES in most species is 10 to 20 mL/kg BW, IV to minimize risk of inducing coagulopathies; reported doses of TES in humans are significantly higher, up to 50 mL/kg/BW per day (13,16,18,21). Due to limited study of TES in the horse and documented increased adverse effects on coagulation at a dose of 40 mL/kg BW, a dose of 20 mL/kg BW was selected in our study in order to maximize clinical effect and to simulate a dose likely to be used in clinical practice (19). A dose of 20 mL/kg BW in adult horses caused significant changes in COP that lasted up to 6 h (19); whereas a significant percentage change from baseline was only present at 1 and 3 h after a 20 mL/kg BW bolus in foals in this report. The comparatively short duration of effect in our study may also have been related to the larger volume of body water and increased clearance in healthy foals as opposed to adult horses. Further study is warranted to assess plasma clearance in septic neonatal foals that may have decreased plasma volume, reduced glomerular filtration rate, and incomplete renal maturation (17,22).

Numerous mechanisms have been suggested for the negative effects of colloid solutions on coagulation, including direct binding of the molecules to coagulation factors, hemodilution, incorporation of colloid molecules into clots, and induction of platelet dysfunction (7,10,13). None of the coagulation parameters measured in this study (platelet number, Factor VIII: C, vWF:Ag, fibrinogen, PT, aPTT) were significantly affected by the infusion of TES, supporting results of other studies suggesting that TES solutions are safer alternatives to older synthetic colloids. Tetrastarch solutions have reduced effects on coagulation compared with pentastarch (PES) and HES solutions, although at higher doses TES can still induce significant changes in coagulation parameters (19). Hemodilution results in dilution of coagulation factors, specifically vWF and Factor VIII: Protein C (16). Interestingly, a bolus dose of 20 mL/kg BW of TES to neonatal foals does not appear to impact these factors in mature horses (19). Hydroxyethyl starch solutions can induce fibrinogen deficiencies in both horses and humans (7,23); and while there was no significant change within groups, the treatment group had significantly lower fibrinogen than the control group at 24 h.

Although acute kidney damage resulting from synthetic colloids has not been documented in the horse, recent reports indicated that the risk of acute renal injury in humans and sheep following administration of synthetic colloids is decreased with lower molecular weight/lower molar substitution solutions (13,15,17,18). In the data reported here, there were no changes indicative of renal damage in the treatment group. Conversely, comparison of TES and balanced crystalloid solution for maintenance of perfusion in an ovine model of endotoxemia identified a protective effect of TES solutions on renal tubular cells; the same group documented increased severity of renal effects with administration of 10% PES *versus* 6% TES (17,24). Given the high prevalence of sepsis and SIRS in hospitalized neonatal foals, the investigation of colloid administration specifically in septic foals is warranted before blanket recommendations about the use of TES in these patients can be made.

Limitations to this study included the use of healthy, euvolemic neonatal foals and limited sampling time points and parameters for renal and coagulation assessment. Controversy exists over the use of HES and TES solutions in sepsis in humans, and while there were no adverse effects in this population the use of these solutions in septic foals should be approached cautiously until further investigation can be performed (21,25,26). Changes were not identified at 24 h in the coagulation parameters assessed in this study; however, the lack of exploration into earlier and more transient effects of TES is a limitation of this study. Twenty-four hours was selected as a sampling point based on the documented effect of HES on activity of vWf:Ag and FVIII:C, and serum levels of fibrinogen in ponies; all of these can remain decreased up to 120 h after an infusion of 10 or 20 mL/kg BW of HES (12). Although platelet numbers were not affected by the administration of TES, platelet function should be assessed in foals in the future as this is a documented effect of synthetic colloids in humans, dogs, and adult horses (7,8,27–29). Future studies should more adequately define the effect on platelet function through platelet aggregometry and platelet function analysis, and clot stability through thromboelastography and dynamic viscoelastic coagulometry (7,10). Given the paucity of information in the literature regarding the effects of synthetic colloids on renal function in the horse, assessing renal parameters at 24 h was determined as a starting point for documenting clinically significant renal damage. In future studies, measuring renal and coagulation parameters at more frequent intervals would be prudent to identify earlier, transient effects of increased COP on these parameters.

This study documented the effects of a low molecular weight/low molar substitution ratio hydroxyethyl starch solution on

clinicopathologic variables and vital parameters in healthy neonatal foals. A significant effect on COP was identified for up to 3 h after infusion of TES, suggesting that TES may have value in resuscitation of hypotensive or hypoproteinemic foals. No adverse effects were noted, thus it appears that TES can safely be administered to healthy, euvolemic neonatal foals.

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