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ORIGINAL ARTICLE

Pretreatment of enteral nutrition with sodium polystyrene sulfonate: effective, but beware the high prevalence of electrolyte derangements in clinical practice

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Abstract

Background: Current treatment options for chronic hyperkalemia in children with chronic kidney disease include dietary restrictions or enteral sodium polystyrene sulfonate (SPS); however, dietary restrictions may compromise adequate nutrition and enteral SPS may be limited by palatability, adverse effects and feeding tube obstruction. A potentially safer alternative is to pretreat enteral nutrition (EN) with SPS prior to consumption. The purpose of this study was to evaluate the efficacy and safety of pretreating EN with SPS in pediatric patients with hyperkalemia.

Methods: We performed a retrospective cohort study between September 2012 and May 2016 at the Children's Hospital of Philadelphia. In all, 14 patients (age range 0.5–53.2 months) who received 19 courses of SPS pretreatment of EN were evaluated. Serum electrolytes were evaluated at baseline and within 1 week of initiating therapy. The primary endpoint was mean change in potassium at 7 days. Secondary endpoints included the mean change in serum sodium, chloride, bicarbonate, calcium, phosphorous and magnesium, as well as the percentage of patients who developed electrolyte abnormalities within the first week of treatment.

Results: Serum potassium levels decreased from 6.0 to 4.4 mmol/L ($P < 0.001$) and serum sodium levels increased from 135.8 to 141.3 mmol/L ($P = 0.008$) 1 week after initiating SPS pretreatment. No significant differences in mean serum calcium or magnesium levels were noted. Nevertheless, more than half of the courses resulted in at least one electrolyte abnormality, with hypokalemia (31.6%), hypernatremia (26.3%) and hypocalcemia (21.1%) occurring most frequently.

Conclusions: Pretreatment of EN with SPS is an effective method for treating chronic hyperkalemia in pediatric patients; however, close monitoring of electrolytes is warranted.

Key words: chronic renal failure, CKD, hyperkalemia, nutrition, pediatrics

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Introduction

The management of hyperkalemia in chronic kidney disease (CKD) is challenging and dietary restrictions are often insufficient. In addition, reductions in dietary intake of potassium may compromise adequate nutrition in pediatric patients, which is important for cerebral and somatic growth [1]. Sodium polystyrene sulfonate (SPS or Kayexalate) is a resin that binds and exchanges potassium for sodium and is licensed for oral or rectal administration to treat elevated serum potassium levels; however, use can be limited due to poor palatability and gastrointestinal or metabolic adverse effects, as well as concern for enteral feeding tube obstruction [2, 3]. Reported metabolic derangements include hypernatremia, hypokalemia, hypocalcemia and hypomagnesemia [3]. Furthermore, bowel necrosis and gastrointestinal obstruction have been reported with enteral use of SPS [2].

A potentially safer alternative to enteral administration is to use SPS off-label to pretreat formula or expressed breast milk (EBM) with SPS and subsequently decant the supernatant and discard the sediment, which contains both the resin and bound potassium. Several *in vitro* studies using various doses of SPS have shown 6–89% reductions in the potassium content of various types of formula or EBM [2–9]. In addition, changes in formula content of other electrolytes, such as increases in sodium [3–9] as well as decreases in calcium [3, 5, 6, 9] and magnesium [3, 6, 9], have also been observed. Although there are several reports of the *in vitro* effects of pretreating EBM or formula with SPS, there are limited patient safety and efficacy data. The purpose of this study is to evaluate the safety and efficacy of pretreating enteral nutrition (EN) with SPS in pediatric patients with hyperkalemia in clinical practice.

Materials and methods

This was an Institutional Review Board approved retrospective chart review. All patients treated at the Children's Hospital of Philadelphia (CHOP) between September 2012 and May 2016 were included for analysis if they were <18 years of age with a diagnosis of hyperkalemia and had received pretreatment of EN with SPS for a minimum of 3 days and had serum electrolytes checked both within 72 h prior to starting and 7 days after the initiation of treatment. Patients were excluded if they were >18 years of age, missing laboratory values, did not have a stable dialysis prescription, were receiving standing scheduled enteral or rectal SPS prior to starting pretreatment of EN (patients receiving intermittent doses for acute management of hyperkalemia were included) or had SPS added to EN without decanting prior to consumption. Patients who received more than one course of SPS-pretreated EN were evaluated more than once.

Hypokalemia was defined as a serum potassium <3.5 mmol/L and hypernatremia was defined as a serum sodium >145 mmol/L. One child who was hypokalemic at baseline was excluded. This patient had received a previous course of SPS-pretreated EN that had been discontinued due to hypokalemia (nadir serum potassium 2.9 mmol/L); SPS pretreatment was reintroduced as the serum potassium was trending up and ultimately discontinued due to recurrence of hypokalemia. No subjects were hypernatremic at baseline. Since many children with CKD or acute kidney injury (AKI) are at risk for hypocalcemia at baseline, we defined clinically significant hypocalcemia in two ways. In patients with a normal initial serum calcium (≥8.8 mg/dL) prior to receiving SPS-pretreated EN, hypocalcemia was defined as the development of serum calcium ≤8.7 mg/dL after SPS pretreatment. In patients with serum calcium ≤8.7 mg/dL at baseline, we defined hypocalcemia as a decrease in serum calcium >1 mg/dL after SPS-pretreated EN exposure. Hyperphosphatemia was defined as any phosphorus value above the upper limit of normal for the patient's age. Estimated glomerular filtration rate was calculated using the bedside Schwartz equation for patients ≥1 year of age [10] and the modified Schwartz equation for patients <1 year of age [11]; a k constant of 0.33 was used for infants with a history of prematurity (gestational age ≤34 weeks) [12].

The primary endpoint was the mean change in serum potassium after receiving EN pretreated with SPS. All non-hemolyzed serum potassium levels obtained 72 h prior to initiation of pretreatment of formula or EBM with SPS were averaged to provide a baseline potassium value. If a patient received enteral or rectal SPS prior to pretreatment of EN with SPS, the last potassium value prior to enteral or rectal SPS was considered. Baseline serum potassium levels were then compared with serum potassium levels obtained 7 days after the initiation of SPS pretreatment using a paired *t*-test. If a patient had received SPS pretreatment for <7 days, the serum potassium obtained within 24 h of the last dose of SPS pretreatment was used. Secondary endpoints included the mean change in serum sodium, chloride, bicarbonate, calcium, phosphorous and magnesium as well as the percentage of patients who developed hypernatremia, hypokalemia or hypocalcemia within the first week of treatment. We also assessed dosing titrations required within the first week of treatment as well as during the entire course of therapy. Descriptive statistical methods were used to evaluate demographic data and dosing titrations. Laboratory parameters were averaged and then compared with baseline values using paired *t*-tests. A P-value <0.05 was considered to be statistically significant and all analyses were performed using a Microsoft Excel 2013 spreadsheet (Microsoft, Redmond, WA, USA).

Method of EN pretreatment with SPS

A dosing protocol and standardized procedure for preparation of SPS-pretreated EN was instituted at CHOP in September 2012. All subjects in this study received EN pretreated with SPS in the same manner. Various formulas, EBM and alterations in caloric density of EN all inevitably result in a different potassium content within the same volume. Consequently, our protocol was designed to dose the SPS pretreatment of EN based on grams of SPS per milliequivalents of potassium (g/mEq K) contained within the EN rather than the volume of formula administered. The starting dose of pretreatment of EN with SPS was initially 0.5–1 g/mEq K, based on available *in vitro* data [2–9]; however, due to anecdotal reports of electrolyte abnormalities within our institution, our starting dose was subsequently decreased to 0.3–0.6 g/mEq K in April 2014. In order to safeguard against potential contamination of EN with SPS, an additional volume of 200 mL of EN was prepared and later discarded during the preparation process. SPS was shaken and then added to EN, which was then shaken vigorously for 1 min. The SPS-treated EN was then placed upright in the refrigerator and undisturbed for 30–60 min. This allowed the SPS and bound potassium to precipitate to the bottom of the bottle. The EN was then decanted, or poured slowly into an empty bottle without disturbing the SPS sediment at the bottom of the container. As stated above, ~200 mL of supernatant remained in the container after decanting and was discarded.

Table 1. Demographics and clinical data

Subject	Gender	Age (months)	Weight (kg)	eGFR (mL/min/1.73 m^2)	Formula (calories/oz if fortified)	Starting SPS dose (g/mEq K)	Duration (days)	Hypokalemia (lowest K)	Hypernatremia (highest Na)	Hypocalcemia (lowest Ca)
1	Male	53.2	20.4	HD	Nutren Jr.	1	5	No	No	Yes (7.4)
2	Female	3	3	17	Sim Advance	0.5	7	No	Yes (150)	No
3	Male	1.7	3.1	21	Sim PM 60/40	0.6	353	No	No	No
4	Female	0.5	2.3	6	Sim PM 60/40 (24)	0.4	190	No	No	No
5	Male	37.9	15.9	100	Pediasure	0.5	103	No	No	No
6a	Male	0.5	2.6	5	Sim PM 60/40	0.7	13	No	No	No
6b	Male	1.5	2.8	5	Sim PM 60/40 (22)	0.7	3	Yes (2.8)	No	Yes (7.3)
6c	Male	1.7	2.8	7	Sim PM 60/40 (22)	0.3	227	No	Yes (147)	No
7	Male	0.7	2.8	10	Sim PM 60/40	0.5	27	No	No	No
8	Male	1	3.6	33	Sim PM 60/40	0.6	429	No	No	No
9	Male	32.9	13.4	PD	Peptamen Jr	0.9	6	Yes (1.7)	No	Yes (4.8)
10	Male	1.2	3.1	10	Sim PM 60/40	0.5	12	No	No	No
11a	Male	37.1	12.4	HD	Peptamen Jr/Renal Cal	0.4	81	Yes (3.2)	Yes (146)	Yes (8.3)
11b	Male	42.5	14.3	HD	Peptamen Jr/Renal Cal	0.3	5	Yes (3.3)	Yes (162)	No
11c	Male	43.5	14.5	HD	Peptamen Jr/Renal Cal	0.3	8	Yes (3.4)	Yes (147)	No
12a	Male	10.6	9	PD	Gerber Good Start (27)	0.8	581	No	No	No
12b	Male	31.1	15.8	PD	Gerber Good Start (27)	0.1	201	No	No	No
13	Male	0.6	2.6	30	Sim PM 60/40 (22)	0.3	460	No	No	No
14	Female	11.2	8.4	PD	Sim PM 60/40 (27)	0.4	89	Yes (3.4)	No	No

Ca, calcium; eGFR, estimated glomerular filtration rate; HD, hemodialysis; K, potassium; Na, sodium; PD, peritoneal dialysis; Sim, Similac.

Results

A total of 32 patients who were ordered for 47 courses of SPS pretreatment of EN were identified during the study period. A total of 28 courses were excluded: 7 for treatment duration <72 h, 7 for missing laboratory data, 5 for SPS being ordered but never administered, 3 for a standing SPS enteral dose, 2 for SPS being mixed in EN but not decanted per protocol, 2 for unstable dialysis prescriptions, 1 for baseline hypokalemia and 1 for age >18 years. In all, 19 courses of SPS-pretreated EN in 14 patients were included for analysis. Demographic and clinical information is summarized in Table 1. The majority of patients had hyperkalemia secondary to CKD with the exception of Subject 5, who had tacrolimus-induced hyperkalemia, and Subjects 1 and 14, who had hyperkalemia secondary to acute on chronic renal failure. The peak potassium prior to starting SPS was 6.4 ± 1 mmol/L (3.9–8.6 mmol/L). Approximately half (10/19) of SPS pretreatment courses were preceded by an enteral SPS dose. The mean starting SPS pretreatment dose was 0.5 ± 0.2 g/mEq K (range 0.1–1) and the median duration of therapy was 81 days [interquartile range (IQR) 7–227].

The mean serum potassium levels decreased from 6.0 ± 0.9 to 4.4 ± 1.2 mmol/L (26% reduction) 7 days after initiating SPS pretreatment of EN ($P < 0.001$). There was a significant increase in the mean serum sodium (135.8 ± 5.1 versus 141.3 ± 7.2 mmol/L; $P = 0.008$) and phosphorus levels (4.7 ± 1.4 versus 5.9 ± 1.6 mg/dL; $P = 0.05$). There was no significant difference in the mean serum chloride, bicarbonate, calcium or magnesium levels (Table 2). During the first week of treatment, 31.6% of courses developed hypokalemia, 26.3% developed hypernatremia and 21.1% developed hypocalcemia. Two patients developed hyperphosphatemia. One of those patients had resolving AKI and had just come off of intermittent hemodialysis and the other patient had a history of intermittent hyperphosphatemia that occurred before and after the SPS pretreatment course. Hypomagnesemia was not observed; however only six patients had available magnesium levels at 7 days. More than half (52.6%) of the courses developed electrolyte abnormalities during the first week of therapy.

Two patients developed potentially life-threatening adverse events. Subject 9 required a 3-day hospitalization for significant electrolyte abnormalities in the setting of receiving EN pretreated with SPS. The patient presented for a routine clinic appointment on Day 6 of SPS pretreatment and was incidentally found to have severe hypokalemia (serum potassium 1.7 mmol/L) and hypocalcemia (serum calcium 4.8 mg/dL and ionized calcium 0.51 mmol/L). The patient was noted to have developed diarrhea and emesis after the initiation of SPS, with associated myalgias and fatigue but no signs of tetany. An EKG was performed and showed a prolonged QTc interval of 501 ms but no ventricular arrhythmias (baseline QTc was 362 ms ~1 year prior). The patient was receiving calcium carbonate with meals for phosphorus binding and was on a stable peritoneal dialysis prescription but was not receiving any other concomitant medications that are associated with lowering electrolytes. Improvement in electrolytes and electrocardiogram (EKG) (serum potassium 4.3 mmol/L, ionized calcium 0.92 mmol/L, QTc 447 ms) were seen with discontinuation of SPS, intravenous and enteral potassium and calcium repletion as well as the addition of potassium to peritoneal dialysis fluid.

Subject 7 had a history of a reducible inguinal hernia and was noted to have abdominal distension, mottling and respiratory distress that led to a code event on Day 27 of SPS treatment. SPS was placed on hold and the patient was taken to the operating room for an exploratory laparotomy, which revealed diffuse intestinal ischemia and led to withdrawal of care. The bowel necrosis was thought to be related to an incarcerated hernia, although the cause of the necrosis remained somewhat elusive. Notably, crystals resembling SPS were found within the appendicial lumen on autopsy, suggesting that despite our rigorous decanting methodologies, exposure to SPS was still possible.

All of the SPS pretreatment courses ultimately resulted in resolution of hyperkalemia; however, two courses (10.5%) had persistent hyperkalemia requiring treatment with oral or rectal SPS during the first week of SPS pretreatment therapy. Subject 4 had a potassium level of 6.8 mmol/L occurring 27 h after initiation of SPS pretreatment that was treated with an oral dose of

Clinical Kidney Journal

Table 2. Pre- and posttreatment electrolyte values[a]

Lab	Pretreatment	Posttreatment	P-value
Sodium, mmol/L ($n = 19$)	135.8 ± 5.1 (125–143)	141.3 ± 7.2 (129–162)	0.008
Potassium, mmol/L ($n = 19$)	6.0 ± 0.9 (3.9–7.5)	4.4 ± 1.2 (1.7–6.3)	<0.001
Chloride, mmol/L ($n = 19$)	97.6 ± 7.6 (83–113)	97.8 ± 8.7 (83–114)	NS
Bicarbonate, mmol/L ($n = 19$)	25.3 ± 5.1 (14–38)	26.8 ± 5.2 (19–39)	NS
Calcium, mg/dL ($n = 19$)	9.8 ± 0.9 (8.3–11.3)	9.3 ± 1.5 (4.8–10.6)	NS
Phosphorus, mg/dL ($n = 12$)	4.7 ± 1.4 (2.4–7.2)	5.9 ± 1.6 (3.8–9.8)	0.05
Magnesium, mg/dL ($n = 6$)	2.3 ± 0.4 (1.9–3.1)	2.2 ± 0.8 (1.1–3.5)	NS

[a]All values are reported as mean ± standard deviation (range).
NS, nonsignificant.

Table 3. Dosing titrations[a]

Efficacy parameter	Value
Starting dose, g/mEq K	0.5 ± 0.2 (0.1–1)
Required dosing titration, *n* (%)	9 (47.4)
Minimum dose, g/mEq K	0.4 ± 0.2 (0.1–1)
Maximum dose, g/mEq K	0.6 ± 0.2 (0.3–1)
Number of dose decreases	0.6 ± 1.2 (0–5)
Number of dose increases	0.8 ± 1.3 (0–5)
Reason for discontinuation ($n = 16$), *n* (%)	
Normalization of potassium	5 (31.3)
Hypokalemia	4 (25)
Formula stopped	3 (18.8)
Hypernatremia	2 (12.5)
Hypocalcemia and hypokalemia	1 (6.3)
Vomiting	1 (6.3)

[a]Values are reported as mean ± standard deviation (range), unless stated otherwise.

SPS and an SPS pretreatment dose increase from 0.4 to 0.5 g/mEq K. Subject 11a had a potassium level of 5.9 mmol/L occurring 21 h after initiation of SPS pretreatment and received an oral dose of SPS and an SPS pretreatment dose increase from 0.4 to 0.9 g/mEq K. One course (Subject 12a) required two dose decreases, from 0.8 g/mEq K to 0.4 and 0.2 g/mEq K, during the first week of therapy due to persistent hypokalemia (serum potassium 3.8–3.9 mmol/L). In all, six courses (31.5%) were discontinued within the first week of therapy, of which four were due to adverse effects (Subjects 2, 6b, 9 and 11b) and two were due to changes in diet (Subjects 1 and 11c). Beyond the first week of therapy, nine (47.4%) SPS courses required at least one dosing adjustment; 31.5% of courses required a dose decrease, most commonly due to hypokalemia (10/11), and 36.8% required a dose increase for recurrence of hyperkalemia. Half of discontinuations were due to adverse effects (Table 3).

Discussion

SPS is a cation exchange resin that preferentially binds potassium ions as sodium is released. Importantly, the resin does not exclusively bind potassium but may also exchange calcium or magnesium. Several prior *in vitro* studies evaluating pretreatment of EN with SPS have shown significant reductions in the formula content of potassium (6–89%) and concomitant increases in the sodium content (86–527%) [3–9]. Most *in vitro* studies have also demonstrated reductions in formula calcium content (8–84%); however, conflicting information is available regarding the effect of pretreatment of formula on magnesium and phosphorus content [3, 5, 6, 9]. Discrepancies reported in the *in vitro* studies are likely due to variations in preparation techniques and dosing.

Enterally administered SPS has been shown to cause gastrointestinal upset and several metabolic derangements, most notably hypernatremia, hypokalemia, hypocalcemia and metabolic alkalosis. Rarely, fecal impaction, intestinal necrosis and intestinal obstruction have been reported. There is A US Food and Drug Administration warning about intestinal necrosis associated with SPS, especially when administered with sorbitol. Increased risk may be associated with a history of intestinal disease or surgery, hypovolemia, prematurity and renal insufficiency or failure [13]. Our institution performed a root-cause analysis after Subject 7 was found to have bowel ischemia in the setting of receiving SPS pretreatment and determined the SPS crystals to be an ancillary finding. Although it was unclear if SPS contributed to this patient's complications and subsequent death, the decision was made to switch our institution's SPS product to a non-sorbitol-containing product.

It has been theorized that pretreating EN with SPS and then decanting the EN to remove the resin and bound potassium limits SPS exposure and therefore decreases the risk for adverse effects [3]. Limited safety information is available, and no adverse effects have been reported prior to our experience [2]. There appears to be a linear dose relationship, with higher doses of SPS predictably being associated with greater reductions in potassium. Pretreating EN with doses of SPS >1 g/mEq K does not appear to confer any additional reduction in potassium content but may result in greater increases in sodium content in EN, ultimately increasing the risk of hypernatremia [7, 8]. Half of the patients in our cohort who received SPS doses ≤0.6 g/mEq K developed adverse effects as compared with 60% of patients who received higher SPS doses. It has been recommended that a starting dose of 0.2–0.3 g/mEq K results in significant reductions in EN potassium content while limiting increases in sodium [7]. Based on this and the toxicity we observed early in our protocol, we changed the starting dose of

SPS pretreatment at our institution from 0.5–1 g/mEq K to 0.3–0.6 g/mEq K. Dosing can then be titrated to a maximum dose of 1 g/mEq K if required for persistent hyperkalemia.

Only two prior studies have described any *in vivo* experience with pretreatment of EN with SPS. In their original description, Bunchman *et al.* [3] briefly described five children who demonstrated a reduction in serum potassium levels (6.94 versus 4.1 mEq/L; $P < 0.01$) after a mean treatment duration of 2.7 months. The therapy was efficacious and they did not detect any hypernatremia, hypomagnesemia or hypocalcemia during the treatment period. More recently, Thompson *et al.* [2] described 13 infants who received pretreatment of EN with SPS for 48 h. Similar to our study, the treatment was efficacious, demonstrating a 24% reduction in serum potassium levels. Notably, they also reported a significant reduction in serum calcium levels (10.7 versus 10.0 mg/dL; $P = 0.014$) with no significant change in serum sodium or magnesium levels. The authors denied any clinically noticeable side effects but did note that, in their experience, many infants require calcium and magnesium supplementation when receiving SPS-treated EN [9]. Although, the five patients described by Bunchman *et al.* [3] had a similar follow-up time to our series, three of them were on peritoneal dialysis, which likely reduced the chance of developing profound electrolyte derangements. Similarly, although the series by Thomson *et al.* [2] had a comparable number of patients to our series, the follow-up time of 48 h was significantly shorter than our 7-day endpoint, potentially making some of the electrolyte abnormalities more difficult to detect.

Our series represents the largest cohort of individuals studied receiving pretreatment of EN with SPS with the longest follow-up time. We studied 19 courses of treatment in 14 patients over a median duration of 81 days (IQR 7–227). Although generally safe and effective (mean serum potassium decreased from 6.0 ± 0.9 to 4.4 ± 1.2 mmol/L), our findings revealed that a surprisingly high number of treatment courses were complicated by hypokalemia (>30%), hypernatremia (>25%) and hypocalcemia (>20%). We also had two patients with potentially life-threatening adverse effects that may have been possibly caused by SPS pretreatment of EN, including bowel necrosis, severe hypokalemia and hypocalcemia. Adverse effects secondary to SPS pretreatment of EN have not previously been reported; our novel observations are likely due to the larger number of patients in our cohort and the extended duration of monitoring. In addition, it is likely that we detected a higher incidence of hypokalemia, hypernatremia and hypocalcemia due to assessing the incidence of each of these abnormalities among patients rather than looking solely at mean electrolyte values. We speculate that our series likely embodies the true representation of the electrolyte derangements associated with pretreatment of EN with SPS in clinical practice. Furthermore, it is unclear if one can prevent all of the SPS from reaching the patient, even under ideal EN pretreatment conditions. Given the frequent electrolyte derangements observed in our population, it is conceivable that some SPS may remain in the EN despite decanting, thereby increasing the likelihood of developing hypokalemia, hypernatremia or hypocalcemia.

Our study had several limitations. The retrospective nature of the study made our outcomes subject to many potential confounding variables, such as intercurrent illness and simultaneous exposure to electrolyte-altering medications. Although all of the patients in this study were exposed to medications or dialysis that may have otherwise contributed to electrolyte abnormalities, these regimens were stable throughout the first week of the SPS treatment course. Nevertheless, even if not entirely contributable to SPS, there is the potential for adverse effects of SPS in clinical practice. Another limitation of this study is that a subset of patients was included multiple times, potentially skewing the data; however, if each patient was only evaluated during their first course of SPS therapy, the rate of complications would be 21.4% for hypokalemia, 21.4% for hypocalcaemia and 14.3% for hypernatremia. This is still a considerably higher complication rate (42.9% overall) as compared with what has previously been published and should warrant careful monitoring when initiating and titrating SPS pretreatment of EN. Furthermore, serum magnesium and phosphorus levels were not checked systematically, which may have prevented our ability to detect any abnormalities. Finally, the observation period for the primary endpoint was only 1 week and additional adverse effects may have occurred outside of that time frame.

Conclusion

A trial of SPS pretreatment of EN may be warranted in situations where dietary potassium restriction is ineffective or compromises adequate nutrition or enteral use of SPS is not tolerated due to palatability or adverse effects. SPS pretreatment of EN is an effective method for treating chronic hyperkalemia in pediatric patients; however, hyperkalemia, hypernatremia and hypocalcemia are common side effects and warrant close monitoring of serum electrolytes. We recommend that serum electrolytes be checked at baseline and within 3–7 days of initiating or titrating SPS pretreatment of EN. Serum electrolytes should be repeated periodically during treatment, particularly in the setting of gastrointestinal illness, titrating dialysis prescriptions or initiating/titrating other medications that may affect serum electrolytes.

Authors' contributions

K.L.P. was responsible for the conception and design, analysis and interpretation of data, drafting and revising the article, providing intellectual content of critical importance to the work described and final approval of the version to be published. E.R.P. was responsible for conception and design, providing intellectual content of critical importance to the work described and final approval of the version to be published. L.C. was responsible for conception and design, analysis and interpretation of data, drafting and revising the article, providing intellectual content of critical importance to the work described and final approval of the version to be published.

Conflict of interest statement

The authors had no involvements that might raise the question of bias in the work reported or in the conclusions, implications or opinions stated. The results presented in this article have not been published previously in whole or part, except in abstract format.

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