A Randomized, Controlled, Double-Blind Crossover Study on the Effects of 1-L Infusions of 6% Hydroxyethyl Starch Suspended in 0.9% Saline (Voluven) and a Balanced Solution (Plasma Volume Redibag) on Blood Volume, Renal Blood Flow Velocity, and Renal Cortical Tissue Perfusion in Healthy Volunteers

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Objective: We compared the effects of intravenous administration of 6% hydroxyethyl starch (maize-derived) in 0.9% saline (Voluven; Fresenius Kabi, Runcorn, United Kingdom) and a "balanced" preparation of 6% hydroxyethyl starch (potato-derived) [Plasma Volume Redibag (PVR); Baxter Healthcare, Thetford, United Kingdom] on renal blood flow velocity and renal cortical tissue perfusion in humans using magnetic resonance imaging.

Background: Hyperchloremia resulting from 0.9% saline infusion may adversely affect renal hemodynamics when compared with balanced crystalloids. This phenomenon has not been studied with colloids.

Methods: Twelve healthy adult male subjects received 1-L intravenous infusions of Voluven or PVR over 30 minutes in a randomized, double-blind manner, with crossover studies 7 to 10 days later. Magnetic resonance imaging proceeded for 60 minutes after commencement of infusion to measure renal artery blood flow velocity and renal cortical perfusion. Blood was sampled, and weight was recorded at 0, 30, 60, 120, 180, and 240 minutes.

Results: Mean peak serum chloride concentrations were 108 and 106 mmol/L, respectively, after Voluven and PVR infusion ($P = 0.032$). Changes in blood volume ($P = 0.867$), strong ion difference ($P = 0.219$), and mean renal artery flow velocity ($P = 0.319$) were similar. However, there was a significant increase in mean renal cortical tissue perfusion after PVR when compared with Voluven ($P = 0.033$). There was no difference in urinary neutrophil gelatinase–associated liopcalin to creatinine ratios after the infusion ($P = 0.164$).

Conclusions: There was no difference in the blood volume–expanding properties of the 2 preparations of 6% hydroxyethyl starch. The balanced starch produced an increase in renal cortical tissue perfusion, a phenomenon not seen with starch in 0.9% saline.

Keywords: balanced crystalloids, 6% hydroxyethyl starch, hyperchloremia, magnetic resonance imaging, renal tissue perfusion, 0.9% saline

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The chloride content (154 mmol/L) of 0.9% saline is 1½ times that of plasma, and the infusion of large volumes of 0.9% saline can cause hyperchloremic acidosis.[1–5] Animal studies have suggested that chloride is the critical determinant for changes in renal blood flow, mediated primarily by effects on afferent and intrarenal arterial vessels.[6–9] Intrarenal infusion of chloride-containing solutions, such as 0.9% saline or ammonium chloride, led to reductions in renal blood flow and glomerular filtration rate (GFR) in greyhound kidneys denervated by autotransplantation.[6] Other animal experiments have shown that K^+-induced reduction in renal vessel diameter was both dependent on and responsive to increasing concentrations of chloride in the extracellular fluid.[8,10] At pathologically elevated concentrations, chloride led to severe renal vasoconstriction in afferent arterioles of rabbit kidneys bathed in solutions of varying concentrations of chloride.[8] We have recently shown, using magnetic resonance imaging (MRI), that healthy adult humans demonstrate a reduction in renal blood flow velocity and renal cortical tissue perfusion after infusion of 2 L of 0.9% saline over 1 hour, changes not seen after a similar infusion of a balanced crystalloid.[5] However, the effects of colloids on renal hemodynamics have not been studied.

In this study, we used a validated experimental model[1,2,5,11] in healthy adult human volunteers to study physiological responses to an intravenous infusion of 1 L of 6% maize-derived hydroxyethyl starch (HES) suspended in 0.9% saline (Voluven; Fresenius-Kabi, Runcorn, United Kingdom) and 6% potato-derived HES suspended in a balanced solution [Plasma Volume Redibag (PVR); Baxter Healthcare, Thetford, United Kingdom] over 30 minutes. The aims of this study were to compare the potential of the infusions to produce:

- hyperchloremic acidosis;
- changes in calculated blood and extravascular fluid volume; and
- changes in renal volume, renal artery blood flow velocity, and renal cortical tissue perfusion using validated MRI techniques.[5,12–14]

SUBJECTS AND METHODS

We performed this randomized, double-blind, crossover study at a university teaching hospital and recruited 12 healthy adult male volunteers with a body weight of 65 to 85 kg after obtaining informed

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written consent. Those with acute illness in the preceding 6 weeks, taking regular medication, with a history of substance abuse, or having factors precluding MRI were excluded. The UK National Research Ethics Service and Medicines and Healthcare Products Regulatory Agency granted approvals. The protocol was registered at http://www.clinicaltrials.gov (NCT01087853) and was similar to what we have used in a previous study on crystalloids.[5]

Sample Size

Compared with colloids in a balanced solution, 1-L infusions of Voluven can increase serum chloride concentrations by a mean (SD) of 4 (3.5) mmol/L,[2] a change anticipated to be adequate to show differences in renal hemodynamics.[5] To detect an increase in serum chloride concentration from 104 to 108 mmol/L after Voluven infusion with an α error of 0.05 and a power of 90%, 10 subjects were required. Allowing for a 20% dropout rate, we recruited 12 subjects.

Randomization and Masking

A randomization sequence was created by the Nottingham Clinical Trials Unit, based on a computer-generated pseudo-random code using random permuted blocks of varying size. There was equal probability to receive one of the colloids on the first study visit. Crossover studies using the alternate colloid were conducted 7 to 10 days later. Only the data manager and an independent pharmacist who masked the infusions and giving sets with an opaque covering had access to the randomization sequence. The allocations were concealed from the investigators until completion of data analyses.

Baseline Assessment

Participants reported at 9:00 am after a fast from midnight and having abstained from alcohol, nicotine, and caffeine from 6:00 pm. They did not eat or drink for the duration of the study. After voiding of the bladder, height and weight were measured to the nearest 0.01 m and 0.1 kg, respectively, using Salter 9000SV3R scales (Salter UK, Tonbridge, Kent, United Kingdom). Participants were allowed to stand to void urine and be weighed, but blood samples were taken after lying in the supine position for at least 10 minutes.

A 16-G venous cannula (BD Venflon; Franklin Lakes, NJ) was inserted into each antecubital fossa (right for blood sampling, left for infusion). An initial 10 mL of blood sample was drawn 10 minutes after cannula insertion for the analysis of full blood cell count, serum electrolytes, urea, creatinine, albumin, and osmolality. A preinfusion urine sample was analyzed both for osmolality and for concentrations of urea, sodium, potassium, creatinine and neutrophil gelatinase–associated lipocalin (NGAL). In addition, a 24-hour urine sample was collected before each study for the calculation of creatinine clearance.

Interventions

Two 500-mL bags of Voluven or PVR (Table 1) were infused over 30 minutes in a random order on separate occasions 7 to 10 days apart with subjects in the supine position, using 2 MRI-compatible infusion pumps (MEDRAD Continuum MR Infusion System; MEDRAD Inc, Warrendale, PA) and starting at time 0. Body weight measurements and blood sampling were repeated at 30, 60, 120, 180, and 240 minutes after the start of infusion.

Participants were permitted to pass urine as needed and, in all cases, at the end of the study. The time of each micturition was noted, and urine volume was measured. Urine pooled over the 4-hour period was analyzed for osmolality and concentrations of urea, creatinine, sodium, potassium, and urinary NGAL.

Hematological and Biochemical Analyses

Hematological and biochemical parameters were measured by methods we have used previously, with interassay imprecision expressed as coefficients of variance of 0.6% to 4%.[1,2,5,11] Urinary NGAL was measured by enzyme-linked immunosorbent assay (BioPorto Diagnostics, Gentofte, Denmark). Interassay variation, expressed as a coefficient of variance (range), was 3.4% (2.5%–8.4%).

TABLE 1. Characteristics of the 2 Colloids

	6% HES in 0.9% Saline (Voluven)	6% HES in Balanced Solution (PVR)
Colloid	HES (maize-derived)	Poly-*O*-2-HES (potato-derived)
Weight of colloid/L	60 g (6%)	60 g (6%)
Weight-average molecular weight of colloid, MW_w	130 kD	130 kD
Molar substitution	0.4	0.42
Sodium, mmol/L	154	130
Chloride, mmol/L	154	112
Potassium, mmol/L	—	5.36
Calcium, mmol/L	—	1
Magnesium, mmol/L	—	1
Acetate, mmol/L	—	27
Strong ion difference, mmol/L	0	23.36
Sodium supplied as	NaCl 9 g/L	NaCl 6 g/L
pH	4.5–5.5	5.0–7.0
Theoretical osmolarity, mOsm/L	308	277
Total solute weight, g/L	9.0	10.43
$[Na^+]$:$[Cl^-]$ ratio	1:1	1.16:1
Colloid oncotic pressure at 37°C, mm Hg	36	21

Derived Values

Creatinine clearance was calculated from a standard formula.[15] Blood volume at time 0 was estimated according to the method described by Nadler et al.[16] Calculations for changes in blood volume and extravascular fluid volume were based on changes in hematocrit and body weight and were made using formulae we have described previously.[2,5]

The apparent strong ion difference (SID_a) was calculated as described by Stewart[17]:

$$SID_a\,(\text{mmol/L}) = [Na^+] + [K^+] - [Cl^-]$$

MRI Protocol

Images were obtained using a 1.5-T Philips Achieva magnetic resonance (MR) scanner (Philips Healthcare Systems, Best, The Netherlands). Subjects were scanned in the supine position using a body transmit and 4-element sensitivity encoding (SENSE) torso coil. The MR protocol consisted of a series of noninvasive MR measurements to assess renal cortical tissue perfusion and renal artery blood flow velocity.

At the start of infusion, data were collected from arterial spin labeling (ASL) and phase-contrast (PC) MRI to determine renal cortical tissue perfusion[14] and renal blood flow velocity,[13] respectively. These scans were then repeated at specific time points over the course of the 30-minute infusion. Each ASL measurement took approximately 5 minutes, and each PC measurement was collected in a single breath-hold. During the infusion, subjects were scanned at 7-minute intervals to assess the time course of the response. After the infusion, an additional 2 sets of PC MRI measurements were obtained such

that measurements were made up to 60 minutes. Before the infusion, a base equilibrium scan and a longitudinal relaxation time (T_1) map[18] were also acquired for quantification of renal cortical tissue perfusion. The details for PC MRI and ASL protocols have been described in our previous work.[5]

Data Analysis

The PC MRI data were analyzed using the Philips Q-flow software (Philips Medical Systems). A region of interest was drawn over the vessel of interest, and the mean velocity (cm/s) over the cardiac cycle, across the vessel, was calculated. In a separate scan session, the within-session reproducibility of measured mean renal artery flow velocity was assessed and the coefficient of variance was found to be 2.7%.

For the ASL data, ASL tag and control images were motion corrected to the base image using FSL (FMRIB Software Library) and difference images (label-control) calculated.[14] Individual difference images were then averaged to create a single-perfusion–weighted difference map. A perfusion (f) map in units of mL/100 g/min was then obtained using a kinetic model[19] using the individual's perfusion-weighted difference image, base equilibrium image, and tissue T_1. Mean renal cortical perfusion values were then estimated by segmenting the kidney into the cortex and medulla tissue type and averaging cortical tissue perfusion values across both kidneys. As with renal artery flow velocity, within-session coefficient of variance of measured renal cortical perfusion was assessed and found to be 3.3%.

Statistical Analysis

Grouped data (Voluven vs PVR) are represented as mean [standard error of mean (SEM)]. The significance of differences between the 2 groups was tested using the repeated-measures analysis of variances with the Bonferroni correction for multiple comparisons and the Student paired t test, with differences being considered significant at $P < 0.05$. GraphPad Prism (version 5.0d) for Macintosh statistical software package (GraphPad Software Inc, La Jolla, CA) was used.

RESULTS

All the 12 male participants approached, with a mean (SEM) age of 21.2 (0.3) years, were recruited. Baseline parameters before each infusion were similar (Table 2). All participants completed both arms of the study and were included in the analysis. None reported adverse events.

Changes in Weight, Blood Volume, and Extravascular Fluid Volume

Weight changes were proportional to the volume of colloid infused and urine excreted (Fig. 1 and Table 3). Both infusions produced similar changes in hematocrit, hemoglobin, and serum albumin concentration, reflecting equivalent plasma dilution (Fig. 1). Initial blood volume expansions of 60% and 53% of the infused volume were observed for Voluven and PVR, respectively. At the end of 4 hours, 29% and 26% of the infused volumes of Voluven and PVR, respectively, remained within the intravascular compartment.

Expansion of the calculated extravascular fluid compartment was similar after the 2 infusions (Fig. 1). At the end of 4 hours compared with baseline, there was a mean negative extravascular volume balance of 159 mL after Voluven infusion and 149 mL after PVR infusion.

Urinary Volumes, Biochemistry, and Urinary NGAL

Differences between the urinary responses to the 2 infusions were not statistically significant (Table 3). The ratio of the urinary concentration of NGAL to creatinine was not increased significantly after either infusion and differences between the infusions were not significant (Fig. 2).

Changes in Serum Biochemistry and SID_a

After infusion of Voluven, serum chloride concentrations peaked at a mean (SEM) of 108 (0.5) mmol/L and remained above the upper limit of the physiological range (105 mmol/L) for the duration of the study (Fig. 3). The peak chloride concentration was 106 (0.5) mmol/L at the end of the PVR infusion, but normochloremia was observed for the rest of the study duration. The differences in peak chloride concentrations at the end of the infusion were statistically significant ($P = 0.032$), but overall differences over the period of study were not statistically significant ($P = 0.088$). Changes in SID_a, venous pH, and concentrations of sodium and potassium were similar after both infusions (Fig. 3) and serum osmolality (Fig. 1).

TABLE 2. Baseline Parameters Before Infusion

	Before 6% HES in 0.9% Saline (Voluven)	Before 6% HES in Balanced Solution (PVR)	*P*
Weight, kg	74.8 (2.1)	74.5 (2.1)	0.916
Height, m	1.81 (0.02)	1.81 (0.02)	1.000
Body mass index, kg/m^2	22.8 (0.6)	22.7 (0.6)	0.912
Hemoglobin, g/dL	14.1 (0.1)	14.2 (0.1)	0.508
Hematocrit	0.433 (0.005)	0.434 (0.005)	0.963
Chloride, mmol/L	103.7 (0.7)	103.5 (0.5)	0.845
Apparent strong ion difference, mmol/L	43.2 (0.9)	43.0 (0.4)	0.853
Bicarbonate, mmol/L	28.9 (0.8)	28.8 (0.7)	0.874
Serum albumin, g/L	43.3 (0.6)	43.2 (0.4)	0.823
Serum osmolality, mOsm/kg	295 (1.2)	296 (2.7)	0.541
Serum creatinine, μmol/L	84 (2.0)	87 (2.7)	0.399
Creatinine clearance, mL/min	128.4 (4.3)	127.3 (4.5)	0.354
Renal artery blood flow velocity, cm/s	25.0 (1.7)	31.9 (4.3)	0.154
Renal cortical tissue perfusion, mL/100 g/min	317 (24)	350 (27)	0.376
Renal volume, mL	344 (15)	340 (13)	0.529
Calculated blood volume, L	5.2 (0.1)	5.2 (0.1)	0.948

N = 12; all values mean (SEM). Differences were not significant for all parameters (Student paired t test).

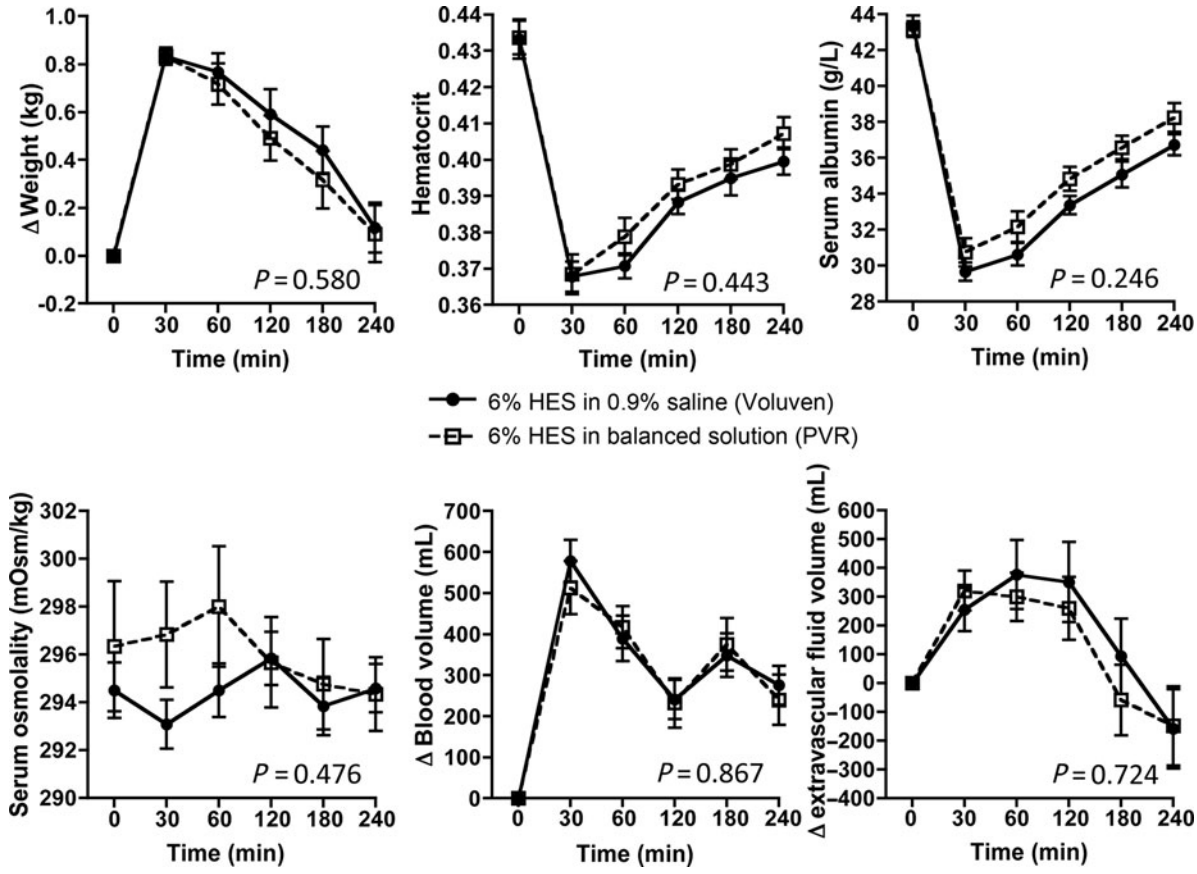

FIGURE 1. Changes in body weight, hematocrit, serum albumin, serum osmolality, blood volume, and extravascular fluid volume after infusion of 1 L of Voluven and PVR over 30 minutes starting at time 0. All values are mean (SEM). *P* values are for the test of Voluven versus PVR using the analysis of variances and a repeated-measures model.

TABLE 3. Urinary Changes

	6% HES in 0.9% Saline (Voluven)	6% HES in Balanced Solution (PVR)	*P*
Time to first micturition after the start of infusion, min	126 (23)	88 (18)	0.063
Postinfusion urinary volume, mL	606 (85)	658 (91)	0.522
Preinfusion urinary osmolality, mOsm/kg	806 (50)	722 (79)	0.207
Postinfusion urinary osmolality, mOsm/kg	581 (60)	507 (73)	0.180
Total postinfusion urinary sodium, mmol	85 (12)	86 (18)	0.937
Total postinfusion urinary potassium, mmol	73 (10)	61 (11)	0.193

N = 12; all values mean (SEM). Statistical significance was calculated using the Student paired *t* test.

Changes in Renal Artery Blood Flow Velocity, Renal Volume, and Renal Cortical Tissue Perfusion Determined by MRI

The responses in renal artery blood flow velocity after the 2 infusions were not significantly different. The increases seen were relatively small, with mean (SEM) peak increases of 4.9 (2.7) cm/s over baseline seen after Voluven infusion and 2.5 (1.2) cm/s after PVR infusion (Fig. 4).

Both infusions increased renal volume, but differences were not statistically significant (Fig. 4). There was a marked increase in renal cortical tissue perfusion after PVR [mean (SEM) peak increase over baseline 25.7 (13.9) mL/100 g/min, equating to a 7% increase from baseline] and a slight decrease [mean (SE) trough −7.9 (6.1) mL/100 g/min, equating to a 2.5% decrease from baseline] after Voluven infusion, a difference that was statistically significant (Fig. 4).

DISCUSSION

Although we have previously shown that the intravenous infusion of 2 L of 0.9% saline over 60 minutes resulted in reductions in renal blood flow velocity and renal cortical tissue perfusion, but not after infusion of a balanced crystalloid,[5] this is the first study to show

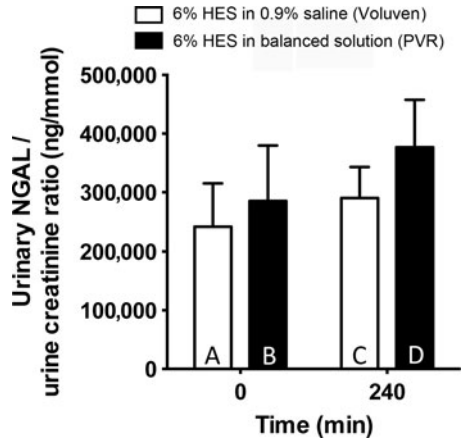

FIGURE 2. Changes in urinary NGAL to urinary creatinine ratio after infusion of 1 L of Voluven and PVR over 30 minutes. All values are mean (SEM). The *P* values are for the test of Voluven versus PVR calculated using the Student paired *t* test. *P* values: A vs B = 0.543; C vs D = 0.164; A vs C = 0.397; B vs D = 0.127.

that a 1-L infusion over 30 minutes of 6% HES in a balanced solution causes an increase in renal cortical tissue perfusion when compared with 6% HES in 0.9% saline. The results of the present study also suggest that as colloids expand intravascular volume to a greater extent than crystalloids, the effects of colloids on renal hemodynamics may be different from those of crystalloids. The data also show that there is no difference in the blood volume efficiency or urinary responses when maize-derived 6% HES is compared with potato-derived 6% HES in healthy euvolemic subjects.

As in previous studies,[1,2,5] we have yet again shown that infusions of even modest volumes of fluids can produce hyperchloremia in healthy volunteers at the end of the infusion. Although the differences for changes in chloride concentration between the 2 infusions used in the present study were significant at the end of the infusions, changes over the time frame of the study were not statistically significant. In addition, although there was a trend for the venous pH to be lower and fall in apparent strong ion difference to be greater after Voluven than after PVR infusion, these differences were not statistically significant. This lack of significance may be because the chloride concentration in PVR at 112 mmol/L is greater than the upper limit of normal in plasma (105 mmol/L). This may also explain the fact that the changes seen in mean renal artery flow velocity were not statistically different when the 2 infusions were compared. Moreover, the greater expansion in blood volume produced by colloids than by crystalloids may

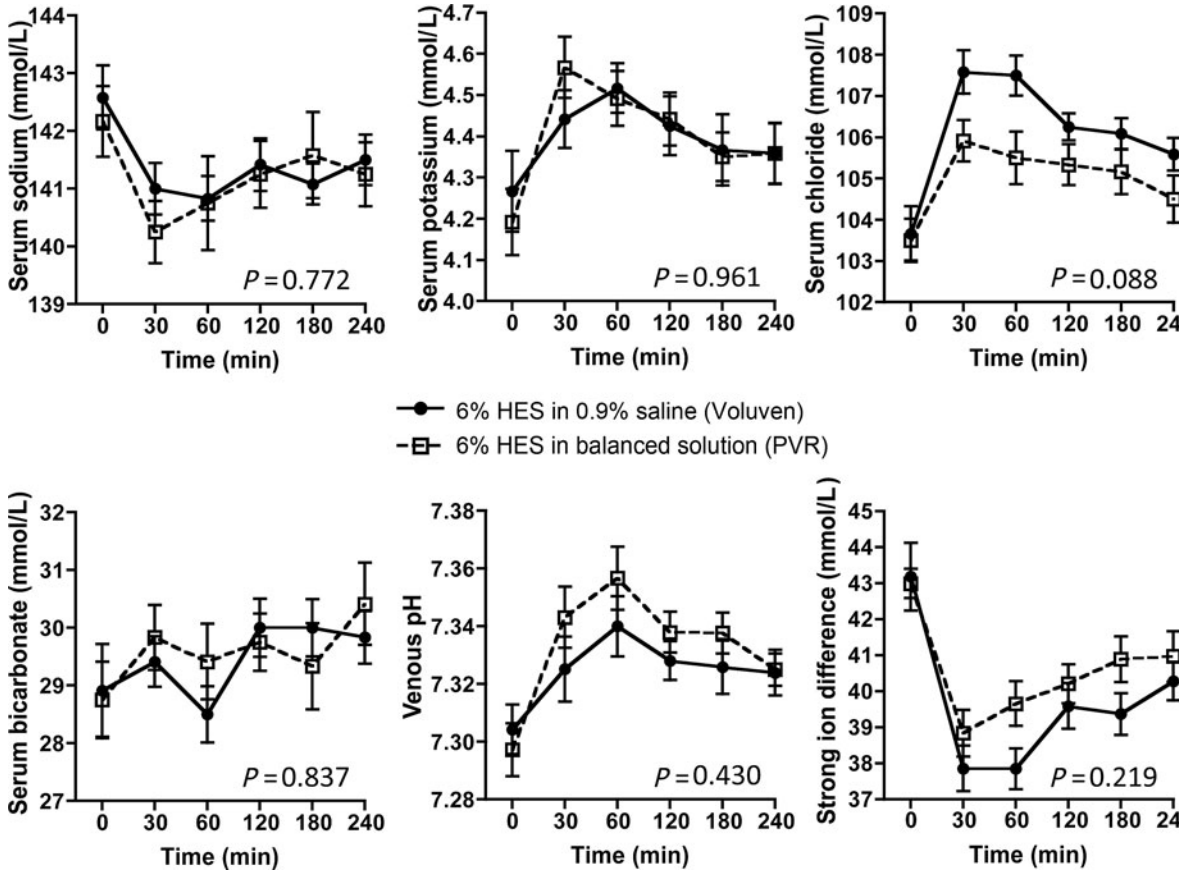

FIGURE 3. Changes in serum sodium, potassium, chloride, bicarbonate, venous pH, and apparent strong ion difference after infusion of 1 L of Voluven and PVR over 30 minutes starting at time 0. All values are mean (SEM). The *P* values are for the test of Voluven versus PVR using the analysis of variances and a repeated-measures model. For the serum chloride concentration, statistically significant differences between the 2 infusions were seen at time points 30 ($P = 0.032$) and 60 minutes ($P = 0.020$).

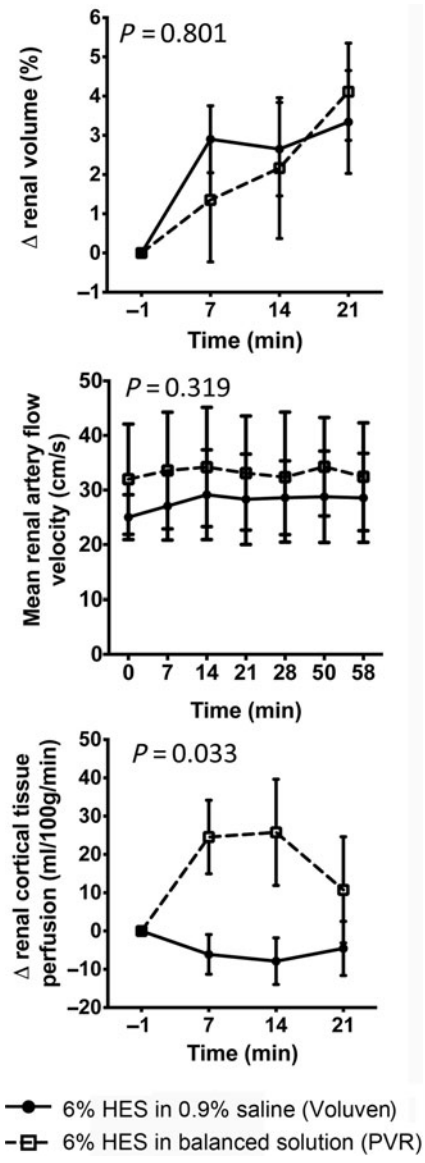

FIGURE 4. Changes in renal artery blood flow velocity, renal volume, and renal cortical tissue perfusion after infusion of 1 L of Voluven and PVR over 30 minutes. All values are mean (SEM). The *P* values are for the test of Voluven versus PVR using the analysis of variances and a repeated-measures model.

explain the lack of difference on renal flow velocity produced by the 2 colloids. When we compared the effects of 2 L of 0.9% saline and a balanced solution over 1 hour, sustained hyperchloremia was produced over the duration of the study by 0.9% saline but not by the balanced crystalloid ($P < 0.0001$), and this resulted in a significant reduction in mean renal artery flow velocity after 0.9% saline but not after the balanced solution ($P = 0.045$). Nevertheless, the increased chloride concentration at the end of Voluven infusion when compared with PVR infusion could have led to inhibition of proximal renal tubular chloride reabsorption, increasing chloride delivery to the distal nephron, with subsequent negative feedback to afferent renal vessels to limit flow,[6] which, although not large enough to be detected by MRI, may have resulted in physiological changes. These chloride-sensitive responses have been confirmed in animal models[9,20] and lead to a reduction in renal artery blood flow, decrease in GFR, and suppression of renin secretion. In addition, the macula densa plays a role in providing tubuloglomerular feedback to afferent vessels and also to the signaling pathway leading to changes in GFR.[21,22] High chloride concentrations in the renal tubules result in the entry of chloride into the cells of the macula densa, leading to depolarization of the basolateral membrane via chloride channels.[23] Depolarization causes adenosine to be released from the macula densa, which, in turn, provides the signal for increased afferent arteriolar resistance and reduced GFR.[21,22] Lack of this intrarenal vasoconstriction after PVR infusion may have resulted in the increase in renal cortical tissue perfusion seen after PVR infusion when compared with Voluven infusion. Changes in circulating volume also influence renal blood flow and perfusion. As the calculated expansion of blood volume after the 2 infusions was identical in the present study, we suggest that the observed differences in renal cortical tissue perfusion are related to the differences in composition of the 2 solutions rather than blood volume expansion. Nevertheless, the relatively smaller magnitude of blood volume expansion and the greater hyperchloremia produced in our crystalloid study may explain why 0.9% saline in that study produced a significant fall in renal cortical tissue perfusion when compared with the balanced crystalloid.[5] Previous animal experiments have also shown that extracellular hyperchloremia has unfavorable effects on vascular resistance,[24,25] GFR,[6,25] and renin activity.[26,27] Although present at low concentrations, it is possible that potassium, calcium, and magnesium ions present in the balanced colloid solution could have lead to enhanced renal perfusion, although mechanisms by which this would occur are unclear. Despite the changes produced in renal hemodynamics, there were no differences observed in urinary responses or urinary NGAL, suggesting that at the volumes infused, no significant renal tubular damage was produced.

This study has several limitations. First, the data were derived from euvolemic healthy subjects and the effects of the colloids in patients undergoing surgery or those with sepsis or critical illness may be different. Expansion of the intravascular volume in euvolemic subjects can lead to the disruption of the endothelial glycocalyx, and this may explain the lower blood volume–expanding efficiency and greater extravascular fluid accumulation seen in the present study than those in hypovolemic subjects.[28–30] However, in patients with existing renal impairment or acidosis, a colloid suspended in a balanced solution may be preferable to one suspended in 0.9% saline. The volume of colloid used was 1 L, as this was thought to be a safe dose over the time period of the infusion in euvolemic subjects. A larger volume may have led to more profound effects on renal hemodynamics. Second, it is difficult to determine whether lack of hyperchloremia caused by PVR resulted in an increase in renal cortical tissue perfusion or whether the hyperchloremia caused by Voluven blunted the increase in renal perfusion caused by colloids per se. Finally, our calculations of blood volume and extravascular fluid volume are not directly measured parameters but derived from changes in weight and hematocrit. This methodology, however, is validated and consistent[1,2,5,11] and is more suitable than isotope or labeled red cell dilution techniques, which cannot be used for serial measurements over a short time period.

Two recent nonrandomized studies have shown that reduction in chloride load delivered intravenously to surgical[31] and critically ill patients[32] results in lower rates of renal dysfunction and acute kidney injury and need for renal replacement therapy. However, 3 large randomized controlled studies in the resuscitation setting comparing HES in a balanced solution with a balanced crystalloid[33] and HES in 0.9% saline with 0.9% saline[34,35] have not shown any benefit of colloid over crystalloid and, perhaps, some detriment to outcome with colloids. It has been hypothesized that renal tubular injury can result

either from direct effects of the starch or secondary to an elevated oncotic pressure. The VISEP study demonstrated that patients with severe sepsis who received a high-molecular-weight (MW) HES solution (MW >200 kD) had an increased risk of acute kidney injury.[35] The recent 6S study showed that patients with severe sepsis who were resuscitated with 6% HES (potato-derived; MW = 130 kD) in a balanced solution had an increased risk of death and were more likely to require renal replacement therapy than patients receiving a balanced crystalloid, Ringer acetate.[33] Most recently, critically ill patients who received 6% HES (maize-derived; MW = 130 kD) in 0.9% saline for fluid resuscitation in the intensive care unit were shown to have an increased requirement for renal replacement therapy when compared with those resuscitated with 0.9% saline.[34]

CONCLUSIONS

We have shown that the infusion of 1 L of PVR over 30 minutes is associated with an increase in renal cortical tissue perfusion, a phenomenon not seen with Voluven. These differences may be attributable to the reduced chloride content of the carrier solution in which PVR is formulated. However, whether this physiological benefit of a colloid suspended in a balanced solution translates into clinical benefit is yet to be determined.

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