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An Acetate-Buffered Balanced Crystalloid Versus 0.9% Saline in Patients with End-Stage Renal Disease Undergoing Cadaveric Renal Transplantation: A Prospective Randomized Controlled Trial

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BACKGROUND: Recent studies have shown a decline in glomerular filtration rate and increased renal vasoconstriction after administration of normal saline when compared with IV solutions with less chloride. In this study, we investigated the impact of normal saline versus a chloride-reduced, acetate-buffered crystalloid on the incidence of hyperkalemia during cadaveric renal transplantation. The incidence of metabolic acidosis and kidney function were secondary aims.
METHODS: In this prospective randomized controlled trial, 150 patients received normal saline or an acetate-buffered balanced crystalloid during and after cadaveric renal transplantation. Venous blood gases were obtained at the start of anesthesia and every 30 minutes until discharge from the postoperative surveillance unit. Serum creatinine and 24-hour urine output were obtained on postoperative days 1, 3, and 7.
RESULTS: Patients received a similar amount of fluid (median: 2625mL [interquartile range: 2000 to 3100] vs 2500 mL [2000 to 3050], $P = 0.83$). Hyperkalemia, defined as serum potassium >5.9 mmol/L, occurred in 13 patients (17%) in the saline and 15 (21%) in the balanced group ($P = 0.56$; difference between proportions −0.037 [−16.5% to 8.9%]). Minimum base excess was lower in the saline group compared with the balanced regimen (−4.5 mmol/L [−6 to −2.4] vs −2.6 mmol/L [−4 to −1], $P < 0.001$) and maximum chloride was significantly higher in the saline group (109 mmol/L [107 to 111] vs 107 mmol/L [105 to 109], $P < 0.001$). No difference in creatinine or urine output was seen postoperatively. Significantly more patients needed catecholamines in the saline group (30% vs 15%, $P = 0.03$).
CONCLUSIONS: The incidence of hyperkalemia differed by less than 17% between groups. Use of balanced crystalloid resulted in less hyperchloremia and metabolic acidosis. Significantly more patients in the saline group required administration of catecholamines for circulatory support. (Anesth Analg 2015;120:123–9)

The choice of IV fluid type for perioperative care has received increasing recent attention.[1] In addition to the debate on synthetic colloid use, the choice of crystalloid has also received considerable attention. In a prospective 2012 trial of 760 critically ill patients, Yunos et al.[2] compared conventional crystalloids to chloride-reduced balanced infusion solutions and found a lower rate of acute kidney injury and less need for renal replacement therapy in the group receiving a chloride-reduced infusion regimen. Despite this and earlier observations that normal saline is unphysiologic,[3] it remains the standard infusion solution in many hospitals.[4] Current evidence demonstrates that the use of normal saline can lead to hyperchloremia and consequently hyperchloremic acidosis.[5–7] Moreover, considerable evidence suggests that infusion of hyperchloremic solutions can cause renal vasoconstriction and a consequent decrease in glomerular filtration rate.[8–10]

Patients with end-stage renal disease receiving renal transplantation may be especially prone to the effects of hyperchloremic infusion solutions due to 2 mechanisms. First, as a result of their failing kidneys, they have a reduced capacity to adapt to hyperchloremia. Second, hyperchloremia induced by infusion of normal saline during the perioperative phase might adversely affect the newly transplanted kidney by inducing renal vasoconstriction. Nevertheless, normal saline remains the most commonly used infusion solution during renal transplantation.[11] Only a few studies have investigated the effects of normal saline compared to a balanced infusion solution in patients undergoing kidney transplantation.[12–15]

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All compared lactated Ringer's solution to normal saline and all found that development of metabolic acidosis and hyperchloremia was more common in the normal saline group. However, these studies were limited by their small number of patients and because almost all patients received living-donor kidney transplantation. Acetate-buffered infusion solutions were also used in only 1 of the studies, which compared normal saline to lactated Ringer's solution and an acetate-buffered balanced solution.[13]

The primary aim of our study was to investigate whether a modern, acetate-buffered chloride-reduced IV solution increases the likelihood of intra- and/or postoperative hyperkalemia, defined as a serum potassium level >5.9 mmol/L when compared to normal saline in patients undergoing cadaveric renal transplantation. In addition to perioperative potassium levels, we measured the incidence of metabolic acidosis, urine output, and indices of renal function on postoperative days 1, 3, and 7 as secondary outcomes.

METHODS

The study was approved by our local IRB (EK 1048/2009), the Ethics Committee of the Medical University of Vienna, Austria, and registered at a clinical trials registry (NCT01075750). Written informed consent was obtained from every patient included in the study. The study was conducted at the Department of Anesthesiology in cooperation with the Department of Nephrology of the Medical University of Vienna.

Inclusion Criteria and Randomization

After obtaining written informed consent, patients aged 18 years or older with end-stage renal disease undergoing cadaveric renal transplantation were included in the study. Exclusion criteria were defined as an age younger than 18 years, refusal of study participation, and a preoperative serum potassium concentration exceeding 5.5 mmol/L. Computer-based randomization was performed using sealed envelopes. Patients were randomized at time of transfer to the preoperative care unit of the Department of Anesthesiology to either receive normal saline (theoretical osmolality: 308 mosmol/kg, potential base excess: –24 mmol/L, Na^+: 154 mmol/L, Cl^-: 154 mmol/L) or a chloride-reduced, acetate-buffered balanced crystalloid (Elomel Isoton®, Fresenius Kabi, Austria, GmbH; theoretical osmolality: 302 mosmol/kg, potential base excess: 0 mmol/L, Na^+: 140 mmol/L, Cl^-: 108 mmol/L, K^+: 5 mmol/L, Ca^{++}: 2,5 mmol/L, Mg^{++}: 1,5 mmol/L, Acetate: 45 mmol/L). No IV fluid was administered before randomization.

All patients received a central venous line as well as 1 peripheral venous line. All patients were tracheally intubated before surgery.

Anesthesia

Patients were monitored according to standards (electrocardiogram [ECG], noninvasive arterial blood pressure, oxygen saturation, and temperature).

Propofol (1–2 mg/kg), cisatracurium (0.1 mg/kg), and fentanyl (1–2 μg/kg) were used for induction of anesthesia. Anesthesia subsequently was maintained with sevoflurane in a carrier gas of 50%–80% inspired oxygen and 20% air. Sevoflurane administration was adjusted by the attending anesthesiologists with the goal of maintaining arterial blood pressure within 20% of baseline values.

Fentanyl was administered according to the patient's requirements. Additional muscle relaxant was given as necessary to maintain 1–2 mechanical twitches in response to supramaximal stimulation (train-of-four stimulation) of the ulnar nerve at the wrist. Ventilation was mechanically controlled to maintain end-tidal carbon dioxide tension near 35 mm Hg. Tidal volume was set between 8 and 10 mL per kilogram lean body weight to keep the peak inspiratory pressure below 30 mm Hg and a positive end-expiratory pressure of 5 mm Hg or higher according to the patient's requirements was administered. Forced-air warming was used to keep patients normothermic.

Fluid Management

Infusion rates for patients during surgery were set at 4 mL per kg of body weight per hour. Additional fluid boluses during surgery were administered if considered necessary by the anesthesiologist. Continuous infusion of either normal saline or acetate-buffered balanced crystalloid of 2 mL/kg/h of ideal body weight was administered after surgery during the postoperative observation time until discharge to the normal ward.

Intravenous catecholamines (i.e., noradrenaline) were used when hypotension, defined as a mean arterial blood pressure <60 mm Hg, persisted after repeated fluid boluses.

Management of Intraoperative Hyperkalemia

If patients developed intraoperative hyperkalemia with signs of ECG changes (elevation in T-waves), calcium-gluconate 1000 mg was administered slowly over 2–3 minutes. In severe cases (i.e., presence of ECG changes and potassium ≥ 6 mmol/L), managing potassium through application of insulin and glucose or administration was performed.

Data and Measurements

The following data were obtained from all patients: age, sex, height, dry weight, actual weight, approximate residual daily urine output, number of prior renal transplantations, presence of donor-specific antibodies, total intraoperative fluid administered, total fluid administered until discharge from the postoperative care unit, use of calcium-gluconate 5/30% glucose solutions, units of insulin administered, sodium-bicarbonate 8.4%, and use of catecholamines.

Venous blood gases were obtained at the start of the case and every 30 minutes after induction of anesthesia until patients were discharged from the postoperative care unit to the normal ward. Venous blood gas analysis was obtained with a Radiometer ABL 720 blood gas analyzer (Radiometer Medical ApS, Brønshøj, Denmark). The following variables were obtained by venous blood gas analysis: pH, pCO_2, bicarbonate, standard base excess, sodium, potassium, chloride, and glucose.

Follow-Up

We gathered data on 24-hour urine output, serum creatinine, and blood urea nitrogen concentration on postoperative days 1, 3, and 7. The follow-up period ended at this time point.

Statistical Analysis

Sample size was calculated on the basis of an expected incidence of hyperkalemia in the balanced infusion group of 5% versus an expected 25% in the normal saline group, derived from previous observations.[12] Modeling was achieved with PS Power and Sample Size Calculations version 2.1.30 using these data and cross-checked using Stata MP/10 for Windows. We calculated that with an α-error of 0.05 and a power of 0.9, 75 patients for each group were needed to produce a significant difference on the 5% level with a power of 90%. However, initially we planned to enroll 200 patients, which we rejected later in the planning phase to avoid unnecessary use of resources.

Statistical analysis was performed by SPSS version 17.0 (Chicago, IL). Distribution of interval variables was assessed using normal plots. Interval variables with a normal distribution are presented as means ± standard deviation. Nonnormally distributed interval variables and ordinal variables are presented as medians with interquartile ranges. Comparisons of all interval and ordinal variables between the saline group and the acetate-buffered balanced crystalloid group were performed using the Mann-Whitney *U* test. Mean differences between groups were reported with 95% confidence intervals. Median differences between groups were reported with 95% confidence intervals using the Hodges-Lehmann method.[16] In addition Wilcoxon-Mann-Whitney odds (WMWodds) were calculated for all variables compared using the Mann-Whitney *U* test.[17,18] Comparisons of categorical variables between the saline group and the acetate-buffered balanced crystalloid group were performed by Fisher exact test and differences in proportions were calculated according to Newcombe[19] using the CIA software version 2.2.0 (by Trevor Bryant, 2009 University of South Hampton, South Hampton, UK).

To test whether serum concentrations of sodium, potassium, chloride, and pH differed between the saline group and the acetate-buffered balanced crystalloid group, we used a generalized estimating equation assuming a normal probability distribution and a first order exponential correlation matrix for repeated observations within 1 patient. For all analyses, statistical significance was defined by a 2-sided $P < 0.05$. Figures were drawn using GraphPadPrism 5.01.

RESULTS

Between May 1, 2010 and February 28, 2013, 150 patients were randomized and included in the study. Seventy-six patients received normal saline and 74 patients acetate-buffered balanced crystalloid. Both groups were comparable in terms of age, sex, height, dry and actual weight, residual daily urine output, number of prior renal transplantations, and presence of donor-specific antibodies. Baseline characteristics are listed in Table 1. The CONSORT flow chart is given in Figure 1.

During surgery, patients in the normal saline group received a median total of 1500 mL (interquartile range: 1100 to 2100) of fluid versus 2000 mL (1175 to 2050) in the balanced crystalloid group [median difference (95% confidence intervals): 0 (−350 to 0), WMWodds: 1.19 (0.84 to 1.66), $P = 0.34$]. The total amount of fluid administered perioperatively did not differ between groups, with the saline group receiving 2625 mL (2000 to 3100) vs 2500 mL (2000 to 3050) in the balanced crystalloid group [median difference (95% confidence intervals): 0 (−300 to 300), WMWodds: 0.99 (0.70 to 1.38), $P = 0.83$].

The incidence of hyperkalemia differed by less than 17% between groups (17% vs 21%, $P = 0.56$; difference between proportions −0.037 [−0.165 to 0.089]) and median change in serum potassium from start of surgery until maximum potassium was similar (0.8 [0.0 to 1.0] vs 0.6 [0.0 to 1.0], $P = 0.44$; difference between medians 0.0 [0.0 to 0.2]). Detailed results on serum potassium between groups are given in Table 2.

Five patients (7%) in the saline group and 3 patients (4%) in the acetate-buffered balanced crystalloid group received calcium chloride for membrane stabilization during surgery [difference between proportions (95% confidence interval): 0.024 (−0.060 to 0.107), $P = 0.72$]. Five percent glucose was administered in 7 (9%) in the saline group versus 6 (9%) in the balanced crystalloid group as part of hyperkalemia treatment [difference between proportions (95% confidence interval): 0.008 (−0.092 to 0.105), $P = 0.99$]. Additionally, 33% glucose was administered in 11 patients (15%) in the saline group versus 16 (22%) in the balanced crystalloid group as part of hyperkalemia treatment [difference between proportions (95% confidence interval): −0.077 (−0.203 to 0.048), $P = 0.29$]. Twenty-five patients (33%) in the saline group and 26 (37%) in the acetate-buffered balanced crystalloid group received insulin [difference between proportions (95% confidence interval): −3.7% (−18.7% to 11.4%), $P = 0.73$]. Five patients (7%) in the saline group and 3 (4%) in the balanced infusion solution group received sodium bicarbonate 8.4% [difference between proportions (95% confidence interval): 0.024 (−0.059 to 0.108), $P = 0.72$]. Significantly, more patients needed catecholamines for circulatory support during surgery in the group receiving normal saline compared to the acetate-buffered balanced crystalloid group (30% vs 15%) [difference between proportions (95% confidence interval): 0.15 (0.014 to 0.108), $P = 0.0278$].

Fluctuations in serum sodium were similar (4 mmol/L [3 to 5] vs 3 mmol/L [2 to 5]), [median difference (95% confidence intervals): 0 (0 to 1), WMWodds: 1.23 (0.89 to 1.74), $P = 0.92$]. However, maximum chloride levels were significantly higher in the saline group (109 mmol/L [107 to 111] vs 107 mmol/L [105 to 109]), [median difference (95% confidence intervals): 2 (1 to 3), WMWodds 2.08 (1.45 to 2.98), $P < 0.001$] as was chloride fluctuation during surgery (4 mmol/L [3 to 6] vs 3 mmol/L [2 to 5]), [median difference (95% confidence intervals): 1 (0 to 2), WMWodds 1.57 (1.13 to 2.24), $P = 0.03$]

Minimum base excess was significantly lower in the normal saline group compared to the balanced crystalloid regimen (−4.5 mmol/L [−6 to −2.4] vs −2.6 mmol/L [−4 to −1], [median difference (95% confidence intervals): −1.9 (−2.7 to −1), WMWodds 2.21 (1.55 to 3.21), $P < 0.001$] Additionally, the change in base excess from start of surgery to base excess minimum was significantly higher in patients receiving normal saline (−4 mmol/L [−5.6 to −2.7] vs −1.6 [−3 to −1]), [median difference (95% confidence intervals): −2.1 (−2.9 to −1.6), WMWodds 3.99 (2.62 to 6.09), $P < 0.001$]. In the regression analysis, there was a significant trend toward hyperchloremia in the saline group compared to the balanced crystalloid group ($P = 0.0246$). Figure 2 gives the course of acid-base variables and electrolytes during surgery and the postoperative surveillance period.

Table 1. Baseline Characteristics of Patients

		Normal saline group			Acetate-buffered balanced crystalloid group			P	Difference between means (95% CI)	Difference between medians (95% CI)	Wilcoxon-Mann-Whitney odds (95% CI)	Difference between proportions (95% CI)
		Count	Percent		Count	Percent						
Sex (male)		48	63		47	64		0.99				–0.004 (–0.154 to 0.148)
Age (years)		76	100	56 ± 13	74	100	54 ± 13	0.35	2 (–2 to 6)		1.22 (0.86 to 1.69)	
Height (cm)		76	100	173 ± 8	74	100	172 ± 10	0.63	1 (–2 to 4)		1.12 (0.80 to 1.56)	
Dry weight (kg)		76	100	80 ± 18	74	100	79 ± 16	0.79	1 (–5 to 7)		0.99 (0.71 to 1.38)	
Actual weight (kg)		76	100	81 ± 19	74	100	80 ± 16	0.74	1 (–5 to 7)		1.01 (0.73 to 1.42)	
Prior kidney transplantations	0	64	84		60	82		0.36				
	1	9	12		7	10						
	2	3	4		4	6						
	3	0	0		1	1						
	5	0	0		1	1						
Residual urine output (mL/24 h)		76	100	500 (0 to 1000)	74	100	250 (0 to 1000)	0.45		0 (0 to 200)	1.23 (0.88 to 1.72)	
Donor-specific antibodies		17	22		16	22		0.99				0.005 (–0.129 to 0.137)
Non–heart beating donor		2	3		1	1		0.99				0.013 (–0.050 to 0.078)
Surgery time (start anesthesia till end of surgery) in minutes		76	100	184 ± 73	72	97	166 ± 77	0.15	18 (–6 to 42)		1.35 (0.96 to 1.90)	

Results are mean ± SD or median (1st to 3rd quartile).

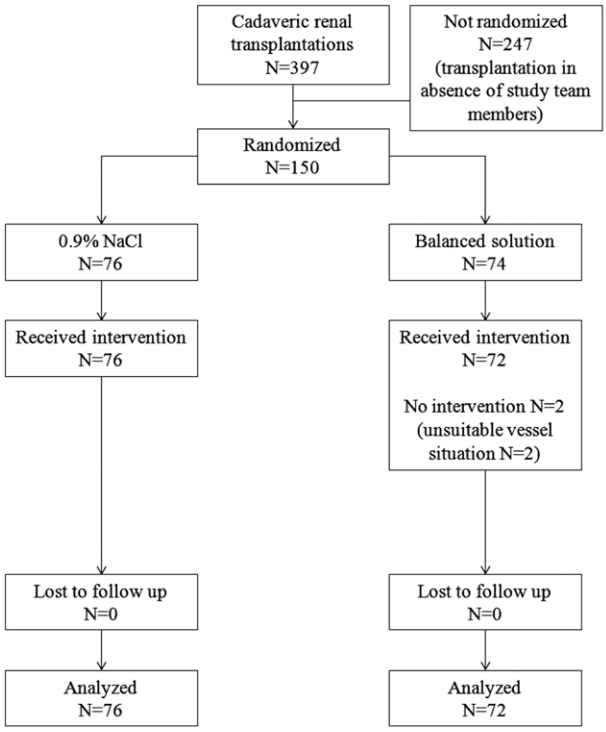

Figure 1. CONSORT flow chart.

There was no difference in the need for dialysis until postoperative day 7 between groups [19 (25%) vs 19 (26%), difference between proportions (95% confidence interval): –0.014 (–0.154 to 0.125), P = 0.85]. With the exception of blood urea nitrogen, which was significantly higher on postoperative day 1 in the balanced crystalloid group, there was no difference between groups in urine output, serum creatinine, and blood urea nitrogen on postoperative days 1, 3, and 7 (Table 3).

DISCUSSION

In this prospective, randomized, controlled study, we compared the effects of normal saline or an acetate-buffered, chloride-reduced crystalloid on the incidence of hyperkalemia and metabolic acidosis in patients receiving cadaveric renal transplantation. We found that, although feared by many anesthesiologists, the use of potassium-containing balanced infusion solution increases the incidence hyperkalemia by no more than 17%. Additionally, acetate-buffered balanced crystalloid was a safe alternative to normal saline, causing less hyperchloremia and consequent metabolic acidosis. Interestingly, patients receiving the chloride-reduced balanced infusion solution showed less need for intraoperative catecholamine use compared to patients receiving normal saline (15% vs 30%).

As was shown by a survey in American transplant centers, more than 90% of patients undergoing kidney transplantation receive normal saline for infusion therapy.[11] The most commonly stated reason for this practice was the fear of inducing hyperkalemia when using potassium-containing infusion solutions such as lactated Ringer's solution, despite the possibility that normal saline-induced hyperchloremic acidosis might itself cause potassium to shift from the intracellular to the extracellular space.[20] Three studies have investigated the effects of normal saline compared to lactated Ringer's solution during renal transplantation.[12,14,15] As in

this study in which an acetate-buffered balanced crystalloid was used, all of these studies found a more stable acid-base state and less electrolyte deviations in the group of patients treated with lactated Ringer's solution. Also, study aims are only clearly defined in 1 of the studies.[12] Although this r study was larger, we could not find a difference in rate of hyperkalemia, maybe due to a stricter preoperative dialysis policy of our treating nephrologists. Hadimioglu et al.[13] compared an acetate-buffered balanced crystalloid to lactated Ringer's solution and normal saline in patients undergoing living donor kidney transplantation. Although they found a significantly lower pH in the saline group, no patients developed acidosis. Also they found a significantly higher urine output on postoperative days 1, 2, and 3 in the normal saline group compared to the balanced crystalloid group.[13]

Recently, Yunos et al.[2] showed in a large collective study of critically ill patients that patients receiving chloride-reduced IV crystalloids had a lower incidence of acute kidney injury and were less likely to require renal replacement therapy. Another 2012 study of healthy volunteers found that when compared to a balanced chloride-reduced infusion solution, IV infusion of 2 L of normal saline reduced mean renal artery flow velocity, renal cortical tissue perfusion, and urine output.[21] In a different study of elderly surgical patients, gastric mucosal perfusion was reduced in patients receiving normal saline compared to those receiving chloride-reduced infusion solutions.[7] Shaw et al.[22] compared major complications and mortality between patients receiving normal saline or an acetate-buffered, chloride-reduced crystalloid on the day of open abdominal surgery. The authors found a significantly higher complication rate and a significantly increased mortality in the saline group compared to those receiving balanced crystalloids. A recent study by McCluskey et al.[23] of more than 22,000 patients undergoing noncardiac surgery found an increase in 30-day postoperative mortality, length of hospital stay, and postoperative renal dysfunction in patients with postoperative hyperchloremia.

Table 2. Results on Serum Potassium Between Groups

	Normal saline				Acetate-buffered balanced crystalloid						
	n (%)	Median	25th percentile	75th percentile	*n* (%)	Median	25th percentile	75th percentile	*P*	Difference between medians (95% CI)	Wilcoxon-Mann-Whitney odds (95% CI)	Difference between proportions (95% CI)
Hyperkalaemia > 5.9 mmol/L	13 (17)				15 (21)				0.68			−0.037 (−0.165 to 0.089)
Hyperkalaemia > 5.4 mmol/L	28 (37)				28 (39)				0.87			−0.020 (−0.173 to 0.133)
Δ potassium		0.8	0.0	1		0.6	0.0	1	0.44	0.0 (0.0 to 0.2)	1.15 (0.82 to 1.60)	
Potassium fluctuation		1.0	0.1	1		1.0	0.0	1	0.61	0.0 (0.0 to 0.1)	1.01 (0.74 to 1.43)	

While Δ potassium was defined as the serum potassium at the start of surgery until maximum potassium concentration. Potassium values are given in mmol/L.

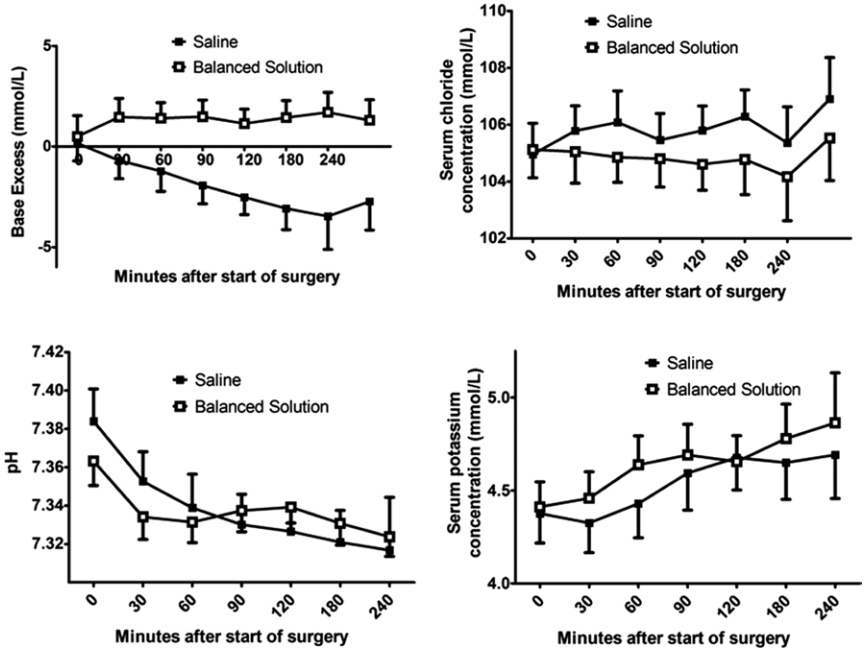

Figure 2. Course of pH, standard base excess, serum chloride, and serum potassium during surgery and the postoperative surveillance period.

Table 3. Results for Follow-Up on Postoperative Days 1, 3, and 7

		Normal saline					Acetate-buffered balanced crystalloid								
	Parameter	Mean	Standard deviation	Median	25th percentile	75th percentile	Mean	Standard deviation	Median	25th percentile	75th percentile	P	Difference between means (95% CI)	Difference between medians (95% CI)	Wilcoxon-Mann-Whitney odds (95% CI)
PO Day 1	Creatinine	7.00	2.36				7.77	2.78				0.071	0.77 (−0.07 to 1.61)		1.42 (1.00 to 1.99)
	BUN	41	14.1				46.9	18.2				0.029	2.7 (0.6 to 11.2)		1.38 (1.00 to 1.99)
	Urine volume			300	50	875			300	25	950	0.97		0 (−100 to 100)	0.99 (0.71 to 1.40)
3	Creatinine	5.79	2.45				6.24	2.69				0.28	0.46 (−0.38 to 1.30)		1.27 (0.90 to 1.77)
	BUN	53.1	16.2				56.3	21.5				0.31	3.2 (−2.9 to 9.4)		1.04 (0.73 to 1.44)
	Urine volume			900	300	1,850			875	400	2,090	0.53		−100 (−400 to 200)	1.13 (0.81 to 1.59)
7	Creatinine	4.93	3.18				4.95	2.92				0.96	0.02 (−0.97 to 1.02)		1.06 (0.75 to 1.48)
	BUN	66.7	31.1				64	26.8				0.57	−2.7 (−12.2 to 6.8)		1.07 (0.76 to 1.50)
	Urine volume			2,310	875	2,950			2,225	1,160	3,125	0.62		−100 (−600 to 350)	1.10 (0.80 to 1.56)

Creatinine and blood urea nitrogen is in mg/dL, and rrine volume is in mL/24 h.
PO = postoperative.

The patient with end-stage renal disease, as in this study, is ideal to study the effects of balanced infusion solutions compared to normal saline since the dramatically impaired kidney function results in a decreased capacity for counter-regulation against metabolic acidosis and hyperchloremia. Although we found no difference in kidney function between the 2 groups, we did demonstrate that using normal saline resulted in metabolic acidosis and hyperchloremia. Both conditions may have potentially unfavorable physiologic effects. Although not a primary end point of our study, patients receiving normal saline were more likely to receive catecholamines for circulatory support during surgery. This effect may plausibly be related to hyperchloremia. In an experimental model of sepsis, hyperchloremic metabolic acidosis increased circulating levels of interleukins 6 and 10 and tumor necrosis factor alpha.[24] In addition, an animal model of experimental sepsis found that hyperchloremia led to a significantly reduced mean arterial blood pressure compared to the group treated with lactated Ringer's solution.[25] A different study on patients undergoing open surgery found that patients in the normal saline group had a reduced gastric mucosal perfusion compared to patients receiving balanced infusion solutions, supporting potentially unfavorable effects of chloride-rich solutions on hemodynamics.[7] The reasons for these findings remain unclear, although data from animal studies suggested that hyperchloremia per se leads to a decreased concentration of angiotensin II and might influence systemic circulation via this pathway.[9]

The results of this study are important not only because a chloride-reduced infusion regimen resulted in fewer metabolic disturbances during renal transplantation but also because the risk of inducing hyperkalemia by a potassium-containing fluid in patients with dramatically impaired kidney function is small. A total infusion volume of approximately 2500 mL during the perioperative period contains 12.5 mmol/L of potassium, This amount is negligible compared to the total body potassium content of about 4000 mmol (50–75 mmol/kg of body weight).[26] Additionally, that more patients (30% vs 15%) in the normal saline group received catecholamines might even have positively influenced serum potassium levels in this group by a shift of potassium to the intracellular space.

We did not see a difference in serum creatinine or urine output on postoperative days 1, 3, and 7 between groups. Previous studies have found discrepant data on this issue.[6,12,13] Unfortunately, there is a lack of long-term outcome data in terms of renal function/graft function in patients receiving chloride-reduced balanced infusion solutions versus those who received normal saline.

We chose to perform an open label study, believing that this should not significantly bias our results in this very special setting of kidney transplantation where the patient is already sedated before start of surgery and then is totally anesthetized. However, the open-labeled design is a limitation of our study. Moreover, it would have been interesting to perform a longer follow-up and/or include data such as postoperative tissue tension, nausea, or headache. Another limiting factor of this study is that it was a pure academic study without financial support. We were only able to randomize patients at a time when 1 of the study members was

present at the hospital. For randomization of all possible patients, a 24-hour/7-day presence would be necessary, which was not feasible due to the lack of financial support.

In conclusion, use of acetate-buffered balanced crystalloid resulted in a difference in hyperkalemia of no more than 17% when compared to use of 0.9NS and did not increase the need for postoperative dialysis. Use of a chloride-reduced, acetate-buffered crystalloid during cadaveric renal transplantation resulted in less hyperchloremia and consequent hyperchloremic metabolic acidosis. Of note, patients in the saline group needed significantly more catecholamines for circulatory support during surgery.

DISCLOSURES

Name: Eva Potura, MD.
Contribution: This author approved the final manuscript.
Attestation: Eva Potura attests to the integrity of the original data and the analysis reported in this manuscript. Dr. Potura is the archival author.
Name: Gregor Lindner, MD.
Contribution: This author approved the final manuscript.
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Name: Peter Biesenbach, MD.
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