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High sodium bicarbonate and acetate hemodialysis: Double-blind crossover comparison of hemodynamic and ventilatory effects

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High sodium bicarbonate and acetate hemodialysis: Double-blind crossover comparison of hemodynamic and ventilatory effects. The superiority of bicarbonate dialysis (Bi HD) over acetate dialysis (Ac HD) using a high sodium dialysate has not been established to our knowledge. We compared Bi HD to Ac HD over 6 weeks each in ten stable patients using a double-blind crossover design and a dialysate sodium concentration of 140 mEq/liter. The dialyzer, delivery system, and disalysate constituents were identical except for the substitution of Bi or Ac. Interdialytic weight gain, pre- and post-HD blood pressures, and heart rates were also comparable in the two protocols. Beginning of the week pre-HD serum Bi was greater during Bi HD than Ac HD (19.1 ± 0.9 vs. 15.1 ± 0.8 mEq/liter, $P < 0.001$); post-HD Bi values were also higher during Bi HD. Similarly, pre-HD pH was also greater with Bi HD (7.40 ± 0.012 vs. 7.35 ± 0.001 U, $P < 0.01$). The number of adverse symptoms and signs were similar during each protocol (2.0 ± 0.65 for Bi HD vs. 2.5 ± 0.5 for Ac HD episodes/patient/6 weeks, NS). However, fewer therapeutic interventions were required during the Bi HD protocol (1.5 ± 0.43 vs. 3.1 ± 0.6 treatments/patient/6 weeks, $P < 0.02$). The ventilatory effects of the two dialysates were evaluated at the end of the 6-week course in seven of the ten patients and revealed comparable declines in carbon dioxide excretion, minute ventilation, and arterial oxygen tension. In summary, these results demonstrate strikingly similar hemodynamic and ventilatory responses with the two dialysates when a higher osmolality dialysate is used. However, Bi HD was associated with a significant reduction in the number of therapeutic interventions required, and also resulted in a greater pre-HD pH and bicarbonate concentration.

Hémodialyse avec des concentrations élevées de bicarbonate ou d'acétate de sodium: Une comparaison croisée en double insu des effets hemodynamiques et ventilatoires. La supériorité de la dialyse avec du bicarbonate (Bi HD) sur la dialyse avec de l'acétate (Ac HD) en utilisant un dialysat riche en sodium n'a pas été établie, à notre connaissance. Nous avons comparé la Bi HD à l'Ac HD pendant 6 semaines chacune avec dix malades stables en utilisant un protocole croisé en double insu, et une concentration de sodium dans le dialysat de 140 mEq/litre. Le dialyseur, le système d'apport, et les constituants du dialysat étaient identiques exceptés en ce qui concerne la substitution de Bi ou Ac. La prise de poids interdialytique, les pressions artérielles pré- et post-HD, et les rythmes cardiaques étaient également comparables dans les deux protocoles. Au début de la semaine avant HD, le Bi sérique était plus élevé durant Bi HD que pendant Ac HD (19.1 ± 0.9 contre 15.1 ± 0.8 mEq/litre, $P < 0.001$); les valeurs de Bi post-HD étaient aussi plus élevées pendant Bi HD. De la même manière, le pH pré-HD était également plus élevé avec Bi HD (7.40 ± 0.012 contre 7.35 ± 0.001 U, $P < 0.01$). Le nombre de symptomes et de signes d'intolérance était identique pendant chaque protocole (2.0 ± 0.65 pour Bi HD contre 2.5 ± 0.5 pour Ac HD épisodes/malade/6 semaines, NS). Cependant moins d'interventions thérapeutiques ont été nécessaires pendant le protocole Bi HD (1.5 ± 0.43 contre 3.1 ± 0.6 traitements/malade/6 semaines, $P < 0.02$). Les effets ventilatoires des deux dialysats ont été étudiés à la fin de la période de 6 semaines chez sept des dix malades et cela a révélé des diminutions comparables de l'excrétion de dioxyde de carbone, de la ventilation par minute, et de la tension artérielle d'oxygène. En résumé, ces résultats démontrent des réponses hémodynamiques et ventilatoires à l'évidence identiques avec les deux dialysats quand une plus forte osmolalité du dialysat est utilisée. Cependant, Bi HD était associé avec réduction significative du nombre d'interventions thérapeutiques nécessaires, et a également été à l'origine d'un bicarbonate et d'un pH pré-HD plus élevés.

The frequency and morbidity of the disabling array of symptoms frequently encountered by patients on chronic hemodialysis have led to a needed investigation into methodology designed to improve the procedure. For example, the routine use of a higher osmolality dialysate in recent studies has been shown to clearly improve the hemodynamic tolerance to dialysis in both acute and longer term trials [1–6]. Another alteration which recently has been purported to markedly improve symptoms on dialysis has been the substitution of bicarbonate for acetate as the base constituent in dialysate. This maneuver has been reported to be associated with fewer hypotensive symptoms [7], less hypoxemia early in dialysis [8–13], improvement in neurologic performance [14, 15], and better maintenance of the cardiac output [16].

However, uniform agreement regarding the advantages of bicarbonate dialysate over acetate dialysate does not exist. Wehle et al [17] noted no added benefit of bicarbonate over acetate, particularly if dialysate sodium was increased to 145 mEq/liter. Similarly, Borges, Fryd, and Kjellstrand [18] failed to document any improvement in the tolerance to weight loss on bicarbonate dialysis in the setting of acute renal failure. Further, Mansell et al [19] have recently demonstrated that patients who developed hyperacetatemia during regular dialysis were still able to maintain an increase in cardiac output. In view of

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Table 1. Dialysis fluid composition

	Acetate	Bicarbonate
Sodium, *mEq/liter*	140	140
Chloride, *mEq/liter*	111.5	106
Potassium, *mEq/liter*	2.0	2.0
Bicarbonate, *mEq/liter*	—	35
Acetate, *mEq/liter*	36	4
Calcium, *mEq/liter*	3.5	3.5
Magnesium, *mEq/liter*	1.5	1.5
Dextrose, *mg/dl*	250	250

Table 2. Weight changes during dialysis study

	Interdialytic weight gain	Intradialytic weight loss
	kg	*kg*
Acetate		
$\bar{x}$	2.15	2.18
SE	0.23	0.12
Bicarbonate		
$\bar{x}$	2.06	2.10
SE	0.14	0.26
P	NS	NS

this on-going controversy regarding the efficacy of bicarbonate dialysate and the expense of changing dialyzer systems to bicarbonate, the need for a randomized, double-blind, crossover study to determine the actual differences in the two dialysates has been recognized [20].

Therefore, the present series of studies were performed in ten dialysis patients (using a double-blind protocol approach) to further elucidate the longer term response to each dialysate. We were particularly interested to learn if any additional benefits could be attributed to bicarbonate dialysate when a dialysate sodium concentration of 140 mEq/liter was employed. Finally, to determine the effects of bicarbonate and acetate dialysate on ventilation and gas exchange, we also performed a series of acute ventilatory studies in seven patients.

Methods

Ten stable chronic hemodialysis patients with intact native kidneys volunteered for the study. The protocol was approved by the Institutional Review Board of the University of Texas Southwestern Medical School, and informed consent was obtained from each of the patients. The mean age of the patients was 59.7 ± 8.1 (SEM) years and the mean length of time on dialysis was 53.8 ± 4.8 months. The etiology of the kidney failure was Kimmelsteil-Wilson Disease (four patients), polycystic kidney disease (two patients), obstructive nephropathy (two patients), and hypertensive nephrosclerosis and interstitial nephritis in one patient each. Four of the patients received antihypertensive medicine chronically. Two of the patients received clonidine only, one clonidine and propranolol, and one hydralazine and minoxidil. The doses of this medicine were not changed during the study. These ten patients were randomly selected on the basis of clinical stability and the likelihood that each could undergo the 12-week protocol without an intervening morbid event. Of these ten subjects, two patients routinely had bouts of significant hypotension on dialysis (≥ 50% of dialyses). Both of these patients were diabetic. Each patient participated in both dialysate protocols which lasted 6 weeks each and consisted of 5-hr dialyses three times per week. The same dialyzer (1.3 m^2 Travenol Hollow-Fiber, Travenol Laboratories, Deerfield, Illinois) and delivery system (Travenol RSP) was utilized for all patients.

The dialysis protocol consisted of a 6-week course (a total of 18 dialyses each) employing acetate-containing dialysate versus bicarbonate-containing dialysate. The content of the two dialysis fluid solutions is listed in Table 1 and was verified by laboratory analysis in each case. Five of the patients began on the acetate dialysate initially, and at the end of the 6 weeks they were switched to the bicarbonate dialysate; the other five patients began with the bicarbonate dialysate and were later switched to the acetate dialysate. The patients and dialysis staff were unaware of the crossover time. The dialysates were prepared prior to the arrival of the patients and medical staff to the dialysis unit. To obviate observer bias in reporting and recording information, the patients, nursing staff, and investigators collecting the data were unaware of which dialysis treatment protocol the patients were undergoing. Further, the results regarding the course of each dialysis were collected from the nursing staff dialysis notes at the conclusion of each dialysis. These records include a constant monitoring of each patient's symptoms (for example, nausea, vomiting, and muscle cramping) and the therapy delivered (intravenous hypertonic saline, normal saline, or mannitol). In the present studies, the following objective symptoms and signs were prospectively designated for inclusion in the data analysis: nausea, vomiting, muscle cramping, diaphoresis, and hypotension. Hypotension was prospectively defined as a systolic blood pressure < 90 mm Hg. Therapies for these events were hypertonic saline, normal saline, or mannitol infusions; the type of therapy administered depended on the severity of the symptoms and the preference of the dialysis staff. Because of the totally blinded nature of these protocols, the dialysis staff occasionally administered therapy for symptoms not prospectively included in the objective signs and symptoms. Thus, the number of therapeutic interventions may exceed the incidence of the prospectively defined signs and symptoms. Supine and standing blood pressures and heart rates were recorded before, during, and at the conclusion of each dialysis. Recumbent blood pressure was routinely recorded every 30 min during the procedure; weights were measured pre- and post-dialysis. Mean arterial blood pressure was calculated by the formula: diastolic blood pressure plus one third of the pulse pressure. Dialyzer blood flow and transmembrane hydrostatic pressure were adjusted depending on the patient's clinical requirement for weight loss; these values were recorded at 30-min intervals. Blood flows (233 ± 1.5 ml/min for bicarbonate vs. 232 ± 3.7 ml/min for acetate, NS) and transmembrane pressures (228 ± 14.4 mm Hg for bicarbonate vs. 204 ± 22 mm Hg for acetate, NS) were comparable in the two protocols. At the beginning of each dialysis week during the study, blood was obtained pre- and post-dialysis for routine chemistries (analyzed by flame photometry and a Technicon Autoanalyzer, Tarrytown, New York), plasma osmolality (freezing point depression, Advanced Instruments, Inc., New Highland, Massachusetts), complete blood count (Coulter Counter), arterial blood gases with the patients breathing room air (IL 813 Blood

Table 3. Comparison of weight, mean blood pressure (MBP), and heart rate (HR) changes during acetate and bicarbonate protocols

	Pre-dialysis				Post-dialysis			
	Weight *kg*	Supine MBP *mm Hg*	Upright MBP *mm Hg*	Supine HR min^{-1}	Weight *kg*	Supine MBP *mm Hg*	Upright MBP *mm Hg*	Supine HR min^{-1}
Acetate								
$\bar{x}$	69.97	99.1	99.5	79	68.13	94.5	90	81.2
SE	4.3	4.1	7.3	3.0	4.3	3.4	6.0	2.6
Bicarbonate								
$\bar{x}$	70.59	96.9	99.4	79	68.71	93.9	90.6	80.5
SE	3.9	3.4	6.3	3.8	4.2	2.8	5.6	2.6
P value	NS	NS	NS	NS	NS	NS	NS	NS

Table 4. Pre- and post-dialysis chemistries[a]

	Sodium		Potassium		Chloride		Bicarbonate	
	Pre	*Post*	*Pre*	*Post*	*Pre*	*Post*	*Pre*	*Post*
Acetate								
$\bar{x}$	140	139	4.94	3.96	101	101	15.1	19.9
SE	0.6	0.5	0.09	0.08	0.4	0.4	0.82	0.60
Bicarbonate								
$\bar{x}$	140	139	5.0	4.0	100	98	19.1	24.7
SE	0.8	0.6	0.09	0.06	0.6	0.6	0.85	0.52
P value	NS	NS	NS	NS	NS	NS	< 0.001	< 0.001

[a] All values are in mEq/liter.

Gas Analyzer, Instrumentation Laboratories, Lexington, Massachusetts). During the course of each dialysis protocol, beginning of the week samples for arterial blood gases were obtained pre-dialysis, at 1 hr, and post-dialysis. The code identifying the order of the protocols was not broken until both protocols had been completed in all of the patients.

In seven of the ten patients, studies of ventilation and gas exchange were performed. These acute studies were performed in the final week of the 6-week bicarbonate or acetate protocols. Timed collections of exhaled gas were collected in a bag collection system (Douglas, Warren E. Collins, Inc., Braintree, Massachusetts) pre-dialysis and at 1 hr of dialysis, measured in a gasometer (Tissot, Warren E. Collins, Inc.), and the volumes were converted to standard temperature and pressure, dry (STPD). The oxygen and carbon dioxide contents of exhaled gas were measured, and from these data total body oxygen consumption (V_{O_2}), carbon dioxide excretion (V_{CO_2}), and respiratory quotient (RQ) were calculated.

Statistics were performed using Student's paired *t* to compare the bicarbonate to acetate results. All data are expressed as the mean ± SE. A *P* value of < 0.05 is considered significant.

Results

Comparison of weights, blood pressures, and heart rate changes during acetate and bicarbonate protocols (Tables 2 and 3). As shown in Table 2, interdialytic weight gains and intradialytic weight losses were similar on both dialysates. As noted in Table 3, these weight changes resulted in comparable pre- and post-dialysis weights, mean blood pressures, and heart rates in both protocols. Pre- and post-dialysis supine to upright mean blood pressures did not decrease significantly in either protocol. Comparison of the pre- to post-dialysis upright mean blood pressure revealed a comparable and significant decline in both protocols ($P < 0.05$).

Comparison of chemistries during acetate and bicarbonate protocols (Tables 4 and 5). Pre- and post-dialysis chemistries were obtained routinely for sodium, potassium, chloride, creatinine, and glucose concentrations. The results are shown in Table 4. As shown in the table, no significant differences in pre- or post-dialysis sodium, potassium, or chloride concentrations were noted between the two dialysate mixtures. During the bicarbonate dialysis protocol, however, pre-dialysis serum bicarbonate was higher than with acetate dialysis (19.1 ± 0.85 vs. 15.1 ± 0.82 mEq/liter, $P < 0.001$). As expected, serum bicarbonate concentration increased significantly with both dialysates; however, post-dialysis serum bicarbonate was higher in the bicarbonate protocol (24.7 ± 0.52 vs. 19.9 ± 0.60 mEq/liter, $P < 0.001$).

No significant differences in other pre-dialysis, beginning of the week chemistries were observed between the two protocols (Table 5).

Comparison of routine arterial blood gases (ABG's) performed during the course of the study (Table 6). Routine ABG's were obtained pre-dialysis, at 1 hr, and post-dialysis at the beginning of the dialysis week in both protocols. Arterial pH was greater pre-dialysis during the bicarbonate protocol, in agreement with the greater bicarbonate concentration pre-dialysis (Table 4). Slight but significant differences were also noted in the pre-dialysis P_{CO_2} (higher with the bicarbonate protocol), and P_{O_2} (lower with bicarbonate). At 1-hr pH and P_{CO_2} were still different, but P_{O_2} had decreased with acetate dialysis so that the pre-dialysis difference was no longer pres-

Table 5. Pre-dialysis beginning of the week chemistries

	BUN	Calcium	Phosphate	Albumin	Plasma osmolality	Hematocrit
	mg/dl				*mOsm/kg H_2O*	%
Acetate						
$\bar{x}$	87.9	9.1	5.0	3.81	318.0	22.4
SE	5.3	0.17	0.5	0.13	1.9	1.1
Bicarbonate						
$\bar{x}$	85.0	9.4	4.7	3.91	307.0	22.5
SE	5.4	0.14	0.35	0.17	8.9	1.2
P value	NS	NS	NS	NS	NS	NS

ent. At the completion of dialysis, this pattern persisted, with pH greater (7.45 ± 0.009 vs. 7.41 ± 0.005, $P < 0.001$) and P_{CO_2} higher (34.7 ± 0.7 vs. 31.2 ± 0.6 mm Hg, $P < 0.005$) with bicarbonate dialysate.

To further examine these differences in ABG's, ventilatory studies using a bag collecting system (Douglas) were performed at the conclusion of the 6-week protocol with each dialysate in seven of the ten patients. These studies were done in addition to the routine ABG collections and included a simultaneous measurement of ABG's and ventilation. Data were collected pre-dialysis and at the 1 hr time period of the procedure. The results of these additional studies are shown in Table 7.

Minute ventilation and carbon dioxide excretion declined at 1 hr in both dialysis protocols; oxygen consumption remained unchanged. Arterial pH and P_{CO_2} were unchanged with acetate dialysate but increased at 1 hr with bicarbonate dialysate. A moderate fall in P_{O_2} occurred in both dialysis procedures; P_{O_2} values were comparable at 1 hr in both protocols.

Comparison of symptoms and signs and therapeutic interventions (Fig. 1). As shown in Figure 1, the frequency of prospectively defined objective signs and symptoms (hypotension, nausea, vomiting, cramps, or diaphoresis) during dialysis was comparable in acetate and bicarbonate dialyses (2.5 ± 0.5 vs. 2.0 ± 0.65 per patient/6 weeks, NS). However, the number of symptoms and signs which were assessed by the dialysis staff to require therapy was significantly less for bicarbonate than acetate HD (1.5 ± 0.43 vs. 3.1 ± 0.6 per patient/6 weeks, $P < 0.02$).

Discussion

The advisability of changing to the routine use of bicarbonate dialysate has recently provoked a great deal of interest and debate because of the central importance of avoiding adverse symptoms during dialysis. The stability of plasma osmolality during dialysis has been shown previously to markedly improve hemodynamic tolerance to weight loss on dialysis [1–6]. In part this hemodynamic stability afforded by a stable plasma osmolality is secondary to improved preservation of the plasma volume during volume reduction on dialysis [3]. At present, however, the ability of bicarbonate dialysate to independently further improve hemodynamic and symptomatic tolerance to hemodialysis when a higher osmolality dialysate is used is unresolved. Accordingly, the present series of studies were designed to address this question, employing a double-blind crossover protocol. In addition, the present experiments also included studies which probe the ventilatory changes associated with both bicarbonate and acetate dialysate.

The amount of weight loss achieved on dialysis was comparable in the two protocols; interdialytic weight gains were also quite similar with both dialysates. Comparable hemodynamic results were obtained during acetate and bicarbonate dialyses (Table 3). Most importantly, post-dialysis mean supine and upright blood pressures were nearly identical in both protocols. The stability of orthostatic mean blood pressure following a weight loss of this magnitude agrees with prior results obtained when plasma osmolality is maintained stable during the dialysis [1, 4]. Although the use of bicarbonate dialysate did not significantly reduce the number of adverse symptoms and signs encountered during the course of the study, the number of therapeutic interventions delivered over the 6-week protocol was reduced on the bicarbonate protocol (Fig. 1). In part, this reduction is because the adverse symptoms and signs encountered by the dialysis staff over the periods of observation were perceived as less severe and were treated less frequently. In the case of the acetate protocol, since the guidelines for therapy were not rigidly controlled, but the reported signs and symptoms were, a greater number of interventions were recorded than symptoms encountered (Fig. 1). From the standpoint of hemodynamic stability and number of symptomatic episodes, this direct comparison of bicarbonate did not reveal detectable differences. From the viewpoint of the number of therapeutic interventions administered, however, a modest but significant improvement with bicarbonate dialysate was observed.

A second area of potential benefit observed with bicarbonate dialysate was found in the pre-dialysis, beginning the week chemistries and ABG's which were obtained during the course of the 6-week trial. Pre-dialysis serum bicarbonate concentration and arterial pH were both significantly greater while the patients were being dialyzed on the bicarbonate protocol. It is of particular interest that the slightly higher post-dialysis pH and serum bicarbonate achieved with bicarbonate dialysate was sustained during the interdialytic interval. This higher pH and serum bicarbonate may be of benefit in retarding the development and reducing the severity of renal osteodystrophy [21], a complicating feature of long-term hemodialysis with cumulative morbid effects. However, whether these improvements in pH and bicarbonate are of sufficient magnitude to alter the course of osteodystrophy is not known. Further, whether these changes would be sustained over a period of years is also unknown.

The acute ventilatory studies performed in seven of the patients extend the ABG results collected over the entire 6-week course of both protocols. The results of the expired gas collections at 1 hr of the procedure demonstrate that during both acetate and bicarbonate dialysis, carbon dioxide diffuses into the dialysate resulting in acute hypoventilation (shown by the decrease in $\dot{V}_E$) in both procedures. During acetate dialysis isocapnea is maintained, but during bicarbonate dialysis bicarbonate diffusion from dialysate induces a respiratory compensation for the metabolic alkalosis, producing a greater degree of hypoventilation (16.5 ± 4% for bicarbonate vs. 9.5 ± 4% for acetate, $P < 0.05$) and therefore a greater increment in arterial P_{CO_2}.

The P_{O_2} results obtained in the acute ventilatory studies and the 6-week studies differ slightly and deserve comment. In the

Table 6. Beginning of the week arterial blood gases

	Pre-dialysis ABG's			1-hr ABG's			Post-dialysis ABG's		
	pH *units*	P_{CO_2} *torr*	P_{O_2} *torr*	pH *units*	P_{CO_2} *torr*	P_{O_2} *torr*	pH *units*	P_{CO_2} *torr*	P_{O_2} *torr*
Acetate									
$\bar{x}$	7.35	31.6	101	7.36	32.2	87.7	7.41	31.2	90.4
SE	0.011	0.71	3.4	0.004	0.52	2.9	0.009	0.6	3.7
Bicarbonate									
$\bar{x}$	7.40	33.4	91	7.40	34.8	90.1	7.45	34.7	85.7
SE	0.012	0.39	3.4	0.008	0.27	3.7	0.009	0.7	4.1
P value	0.01	0.05	0.02	0.01	0.001	NS	0.001	0.005	NS

Table 7. Simultaneous ABG and ventilatory studies pre-dialysis and at 1 hr

	$\dot{V}_E$		$\dot{V}_{CO_2}$		$\dot{V}_{O_2}$		P_{CO_2}		P_{O_2}		pH	
	Pre	1 hr	Pre	1 hr	Pre	1 hr	Pre	1 hr	Pre	1 hr	Pre	1 hr
	liters/min		*ml/min*		*ml/min*		*torr*		*torr*		*units*	
Acetate												
$\bar{x}$	10.8	9.6	222	175	260	244	32	32	92	85	7.39	7.37
SE	1.2	0.8	26	15	26	22	2	2	6	6	0.02	0.01
P	0.05		0.01		NS		NS		0.05		NS	
Bicarbonate												
$\bar{x}$	12.7	10.2	245	198	280	254	33	37[a]	98	87	7.41	7.42[a]
SE	2.7	1.9	23	18	21	25	3	3	6	6	0.02	0.02
P	0.05		0.02		NS		0.05		0.05		0.05	

Abbreviations: $\dot{V}_E$, minute ventilation; $\dot{V}_{CO_2}$, carbon dioxide excretion; $\dot{V}_{O_2}$, oxygen consumption.
[a] $P < 0.05$, bicarbonate vs. acetate.

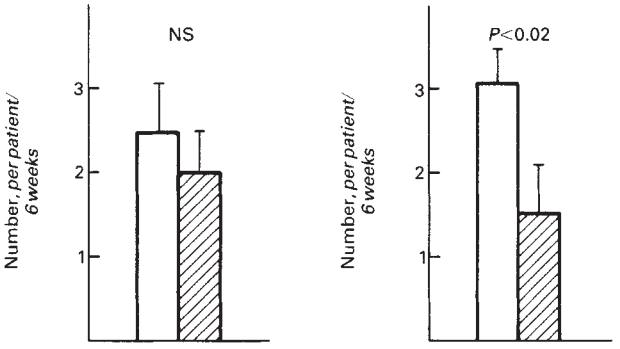

Fig. 1. *Symptoms and therapeutic interventions during dialysis protocols.* The *left panel* represents the symptoms and signs during dialysis ($\bar{x}$ + SE) and the *right panel* therapeutic interventions ($\bar{x}$ + SE). Symbols are: □, acetate dialysate; ▨, bicarbonate dialysate.

acute ventilatory studies, the baseline PO_2 values were comparable with both dialysates and a modest but significant decline in PO_2 occurred during the first hour. In contrast, in the ABG data collected from all ten patients over the course of the 6-week protocol, the mean baseline PO_2 was significantly higher during the acetate protocol than during the bicarbonate trial. However, a sharp decline in PO_2 during the first hour of dialysis was noted with acetate dialysate, and this decline resulted in comparable values for acetate and bicarbonate at 1 hr. Both the acute ventilatory studies and the longer term results agree in that comparable PO_2 values are present with both dialysates at 1 hr. The acute ventilatory results further demonstrate a clear decline in $\dot{V}_{CO_2}$ and $\dot{V}_E$ with both dialysates and agree with the recent results of Eiser et al [22] using baths of similar composition. These authors also reported an increase in $\dot{V}_{O_2}$ during acetate dialysis; however, no increase in $\dot{V}_{O_2}$ was observed with the dialysates in this study. The reasons for this difference are unclear at present.

In summary, the results of this prospective direct comparison of acetate and bicarbonate dialysates in the setting of a higher dialysate sodium concentration (140 mEq/liter) show comparable hemodynamic results (as assessed by orthostatic tolerance to weight loss and heart rate changes). In addition, the incidence of hypotension and several other adverse symptoms during dialysis was also similar, although treatment interventions were reduced significantly during the bicarbonate protocol. Patients also had higher serum bicarbonate and pH values pre- and post-dialysis while on bicarbonate dialysate, but a slightly greater degree of hypoventilation also occurred during the bicarbonate protocol at 1 hr. In the aggregate, bicarbonate dialysate offers only moderate improvement over acetate dialysate when a dialysate sodium of at least 140 mEq/liter is used.

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