Electrolyte Imbalance in HDF

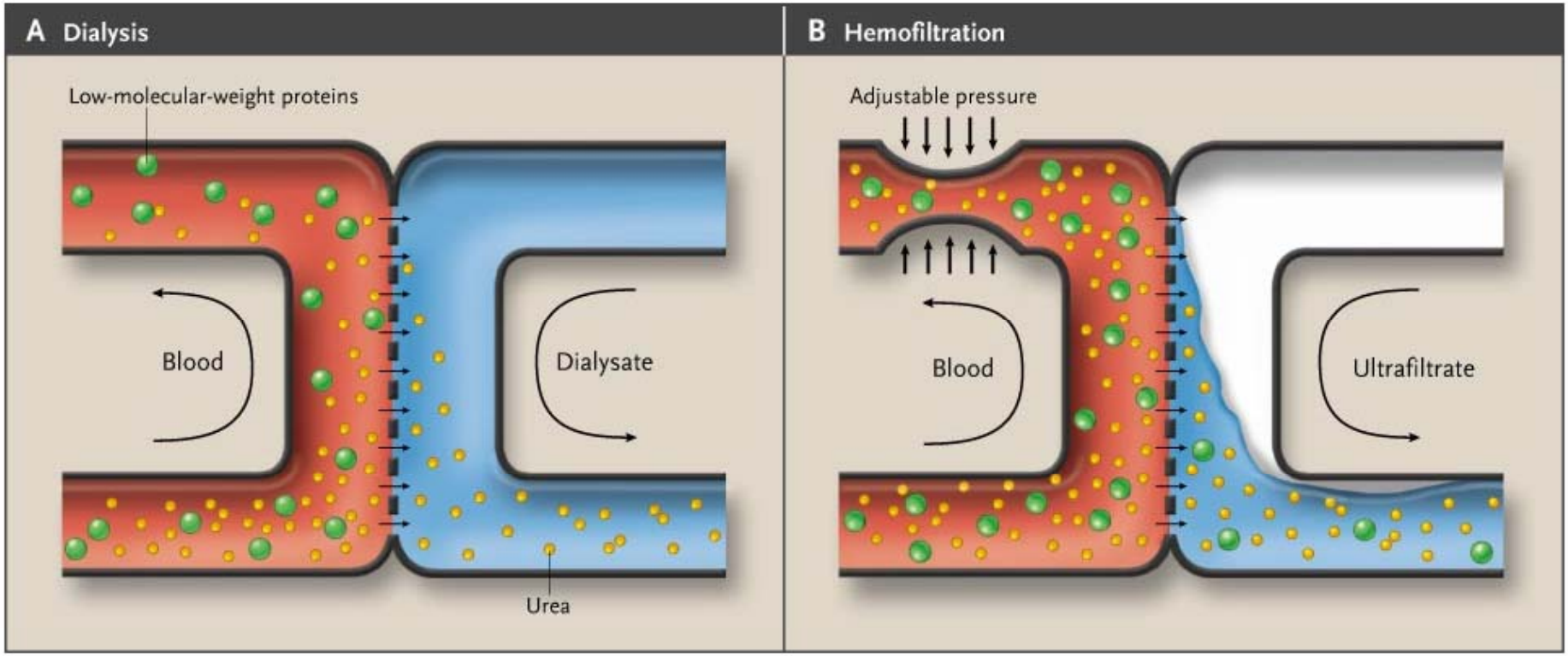
- Comparison of electrolyte profiles between HD and olHDF -

Gheun-Ho Kim, MD

Hanyang University College of Medicine

HDF

= HD (diffusion, small solutes) **+ HF** (convection, larger solutes)



N Engl J Med 357: 1316-1325, 2007

Fluid replacement in online HDF

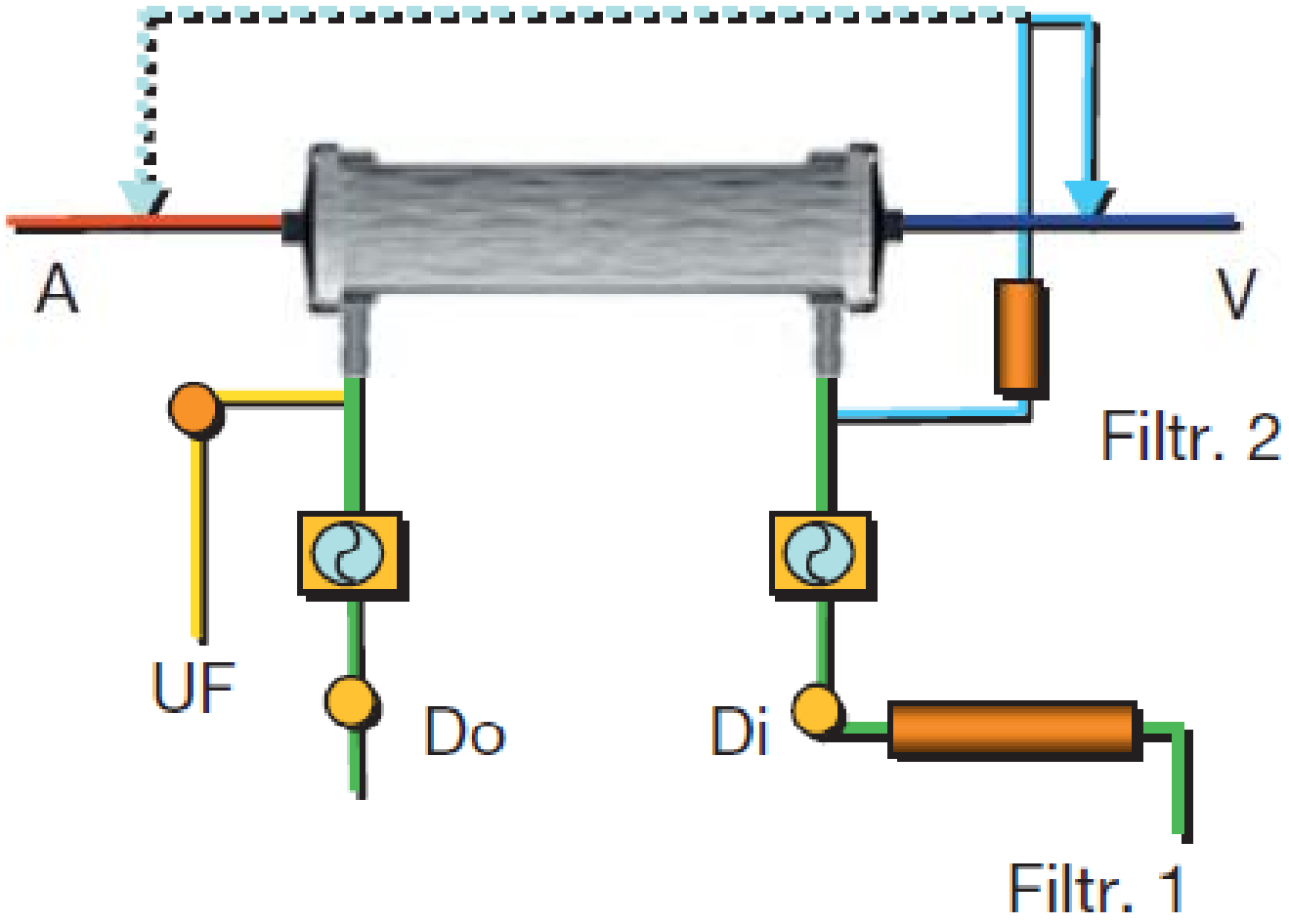


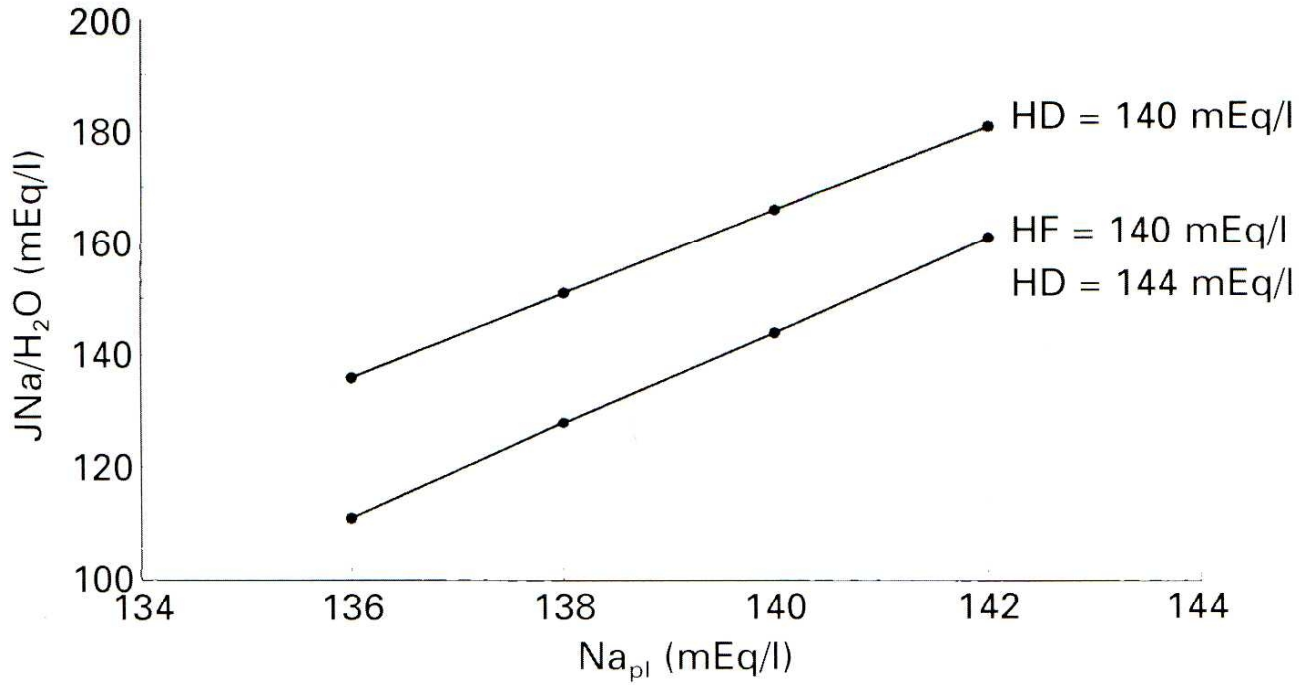
TABLE 1. TYPICAL COMPOSITION OF HEMOFILTRATION REPLACEMENT FLUID.*

* CRRT

COMPONENT	VALUE
	mmol/liter
Sodium	140
Potassium	0
Calcium	1.6
Magnesium	0.75
Chloride	101
Lactate	45
Glucose	11

N Engl J Med 336: 1303-1309, 1997

Estimated sodium removal expressed as mEq/l of water in HF and HD for similar sodium concentrations in the dialysate and in the replacement fluid



HF, hemofiltration; HD, hemodialysis

For a sodium plasma concentration ranging from 136 to 142 mEq/l, sodium removal is always lower in HF. An equivalent sodium removal can be obtained in HD by using a higher dialysate sodium concentration (144 mEq/l).

Nephrol Dial Transplant 15 (Suppl 2): 37–44, 2000

Nephrol Dial Transplant (2004) 19: 2354–2359
DOI: 10.1093/ndt/gfh315
Advance Access publication 20 July 2004

Original Article

Nephrology Dialysis Transplantation

Haemodynamics and electrolyte balance: a comparison between on-line pre-dilution haemofiltration and haemodialysis

Charles Beerenhout, Tom Dejagere, Frank M. van der Sande, Otto Bekers, Karel M. Leunissen and Jeroen P. Kooman

Department of Internal Medicine and Clinical Chemistry, University Hospital Maastricht, The Netherlands

Balances for **sodium**, **potassium**, **calcium** and conductivity were assessed using total dialysate/filtrate collections.

Solute balances (mmol/session) during HD were calculated according to the following formula: $\mathbf{V_{out}} \times \mathbf{C_{out}} - \mathbf{V_{in}} \times \mathbf{C_{in}}$, in which V_{out} = volume of spent dialysate, C_{out} = concentration of solute in spent dialysate, V_{in} = volume of fresh dialysate, C_{in} = concentration of solute in dialysate.

Solute balance during hemofiltration (HF) and hemodialysis (HD)

	HF	HD
Sodium (mmol/treatment)	−436 ± 278	−365 ± 233
Potassium (mmol/treatment)	−92 ± 28	−88 ± 22
Calcium (mmol/treatment)	−4.6 ± 7.1	−4.8 ± 6.5
Phosphate (mmol/treatment)	−30.4 ± 6.0	−29.2 ± 9.0
Conductivity (mS/cm/treatment)	−61.5 ± 12.4	−52.4 ± 8.8

No difference in small electrolyte balance was observed between HF and HD, suggesting that ionic removal is not impaired during on-line HF.

Nephrol Dial Transplant 19: 2354–2359, 2004

J Am Soc Nephrol 11: 2344–2350, 2000

A Comparison of On-Line Hemodiafiltration and High-Flux Hemodialysis: A Prospective Clinical Study

RICHARD A. WARD,* BÄRBEL SCHMIDT,† JEANNINE HULLIN,† GÜNTHER F. HILLEBRAND,†‡ and WALTER SAMTLEBEN†‡

**Department of Medicine, University of Louisville, Louisville, Kentucky; †Department of Medicine I, Klinikum Grosshadern, University of Munich, Munich, and ‡Kuratorium fuer Dialyse und Nierentransplantation, Neuried, Germany.*

Table 1. Patient demographics and treatment prescriptions[a]

	Hemodiafiltration (n = 24)	High-Flux Hemodialysis (n = 21)
Gender (M:F)	15:9	14:7
Age (yr)	61 ± 3	52 ± 3
Cause of ESRD	GN (6), HTN (4), DNS (3), IgA nephropathy (3), PCKD (2), amyloidosis (1), urolithiasis (1), pyelonephritis (1), unknown (3)	GN (9), PCKD (5), DNS (3), Balkan nephritis (1), reflux (1), unknown (2)
Duration of dialysis (mo)	47 ± 9	68 ± 16
Weight (kg)	66.7 ± 2.9	66.6 ± 2.8
Body mass index (kg/m^2)	22.9 ± 0.8	22.7 ± 0.7
Treatment time (min)	247 ± 3	251 ± 6
Blood flow rate (ml/min)	281 ± 4	274 ± 4
Ultrafiltration volume (L)[b]	21 ± 1	2.9 ± 0.2

[a] DNS, diabetes; GN, glomerulonephritis; HTN, hypertension; PCKD, polycystic kidney disease.
[b] Prescribed filtration volume after maximization based on transmembrane pressure (see text).

The **dialysate** contained **138 mmol/L sodium**, **1 to 4 mmol/L potassium**, 1.75 mmol/L calcium, 0.5 mmol/L magnesium, **32 mmol/L bicarbonate**, 3 mmol/L acetate, and 1 g/L glucose.

Table 2. Average predialysis serum electrolyte, urea, and creatinine concentrations over the 12-mo study period

	Hemodiafiltration (n = 24)	High-flux hemodialysis (n = 21)	P[a]
Sodium (mmol/L)	139 ± 1	139 ± 1	0.238
Potassium (mmol/L)	5.8 ± 0.1	5.8 ± 0.1	0.740
Calcium (mmol/L)	2.30 ± 0.02	2.28 ± 0.03	0.616
Inorganic phosphorus (mg/dl)	4.8 ± 0.2	4.9 ± 0.3	0.767
Bicarbonate (mmol/L)	21.3 ± 0.3	19.6 ± 0.3	<0.001
Urea (mg/dl)	143 ± 5	162 ± 5	<0.001
Creatinine (mg/dl)	9.7 ± 0.4	11.5 ± 0.4	0.005

[a] P values indicate the significance of the difference between hemodiafiltration and high-flux hemodialysis.

Long-Term Outcomes in Online Hemodiafiltration and High-Flux Hemodialysis: A Comparative Analysis

Enric Vilar,*† Andrew C. Fry,* David Wellsted,‡ James E. Tattersall,§ Roger N. Greenwood,* and Ken Farrington*

**Renal Unit, Lister Hospital, Stevenage, United Kingdom; †Department of Life Sciences and ‡East of England Research Development Support Unit, University of Hertfordshire, Hertfordshire, United Kingdom; and §Department of Renal Medicine, St James's University Hospital, Leeds, United Kingdom*

Clin J Am Soc Nephrol 4: 1944–1953, 2009

858 incident patients in **high-flux HD (626, 73%)** vs. **online HDF (232, 27%)**

Total Kt/V, **serum albumin**, **erythropoietin resistance index**, and **BP** were similar in both groups up to 5 yr after HD initiation. **Intradialytic hypotension** was less frequent in the predominant HDF group. Predominant HDF treatment was associated with **a reduced risk for death** after correction for confounding variables.

Clin J Am Soc Nephrol 4: 1944–1953, 2009

Dialysate and replacement fluid ion concentrations were as follows: **Sodium 138 mmol/L**, chloride 108.5 mmol/L, **bicarbonate 32 mmol/L**, acetate 3 mmol/L, calcium 1.25 mmol/L, magnesium 0.5 mmol/L, glucose 5.5 mmol/L, and **potassium 2 mmol/L**.

There were **no differences in serum sodium, potassium, and bicarbonate between the groups** at any time point up to 60 months except for a higher mean potassium at 6 months in HDF patients.

Parameter	Group	3 Mo	6 Mo	12 Mo	24 Mo	36 Mo	48 Mo	60 Mo
Sodium	HD mean	138.1	138.1	138.0	138.0	137.9	138.3	137.5
(mmol/L)	HDF mean	137.7	138.4	138.7	138.3	137.5	138.1	138.4
	P	*0.413*	*0.362*	*0.051*	*0.580*	*0.421*	*0.720*	*0.169*
Potassium	HD mean	4.8	4.9	4.9	5.1	5.2	5.1	5.3
(mmol/L)	HDF mean	4.9	5.1	5.1	5.1	5.2	5.2	5.3
	P	*0.320*	*0.006*	*0.125*	*0.820*	*0.579*	*0.494*	*0.859*
Bicarbonate	HD mean	23.5	23.2	23.2	23.0	23.0	23.0	23.6
(mmol/L)	HDF mean	23.6	22.6	23.0	23.0	22.5	22.9	23.1
	P	*0.718*	*0.142*	*0.658*	*0.981*	*0.171*	*0.825*	*0.424*

The International Journal of Artificial Organs / Vol. 21 / no. 6, 1998 / pp. 321-327

Artificial Kidney and Dialysis

On-line hemodiafiltration with pre- and postdilution: impact on the acid-base status

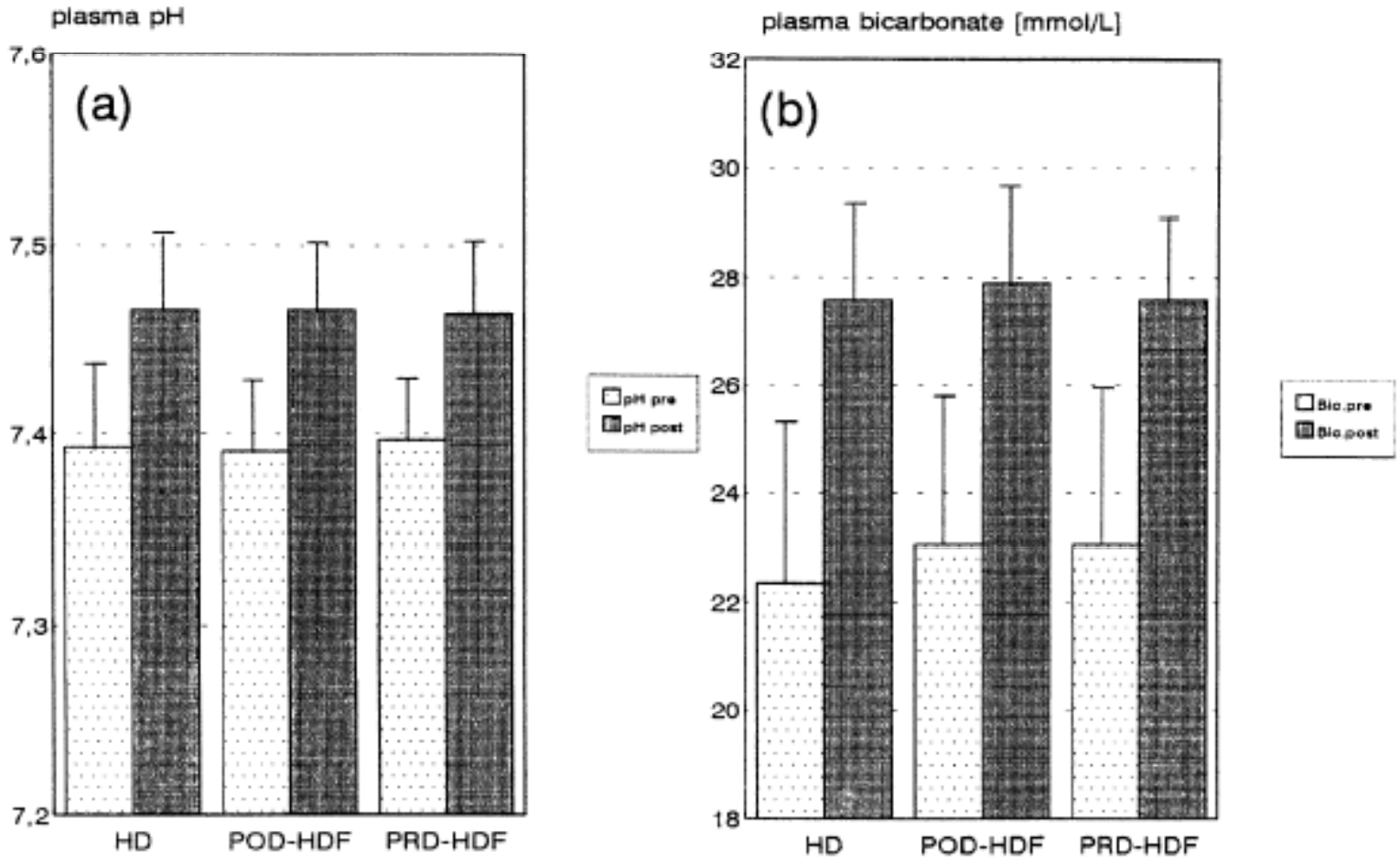
P. AHRENHOLZ[1], R.E. WINKLER[2], W. RAMLOW[2], M. TIESS[2], O. THEWS[3]

[1] BioArtProducts GmbH Rostock
[2] Dialyse-Gemeinschaft Nord e.V. Rostock
[3] Johannes Gutenberg Mainz, Institute of Physiology, Mainz - Germany

TREATMENT PARAMETERS (n = 50)

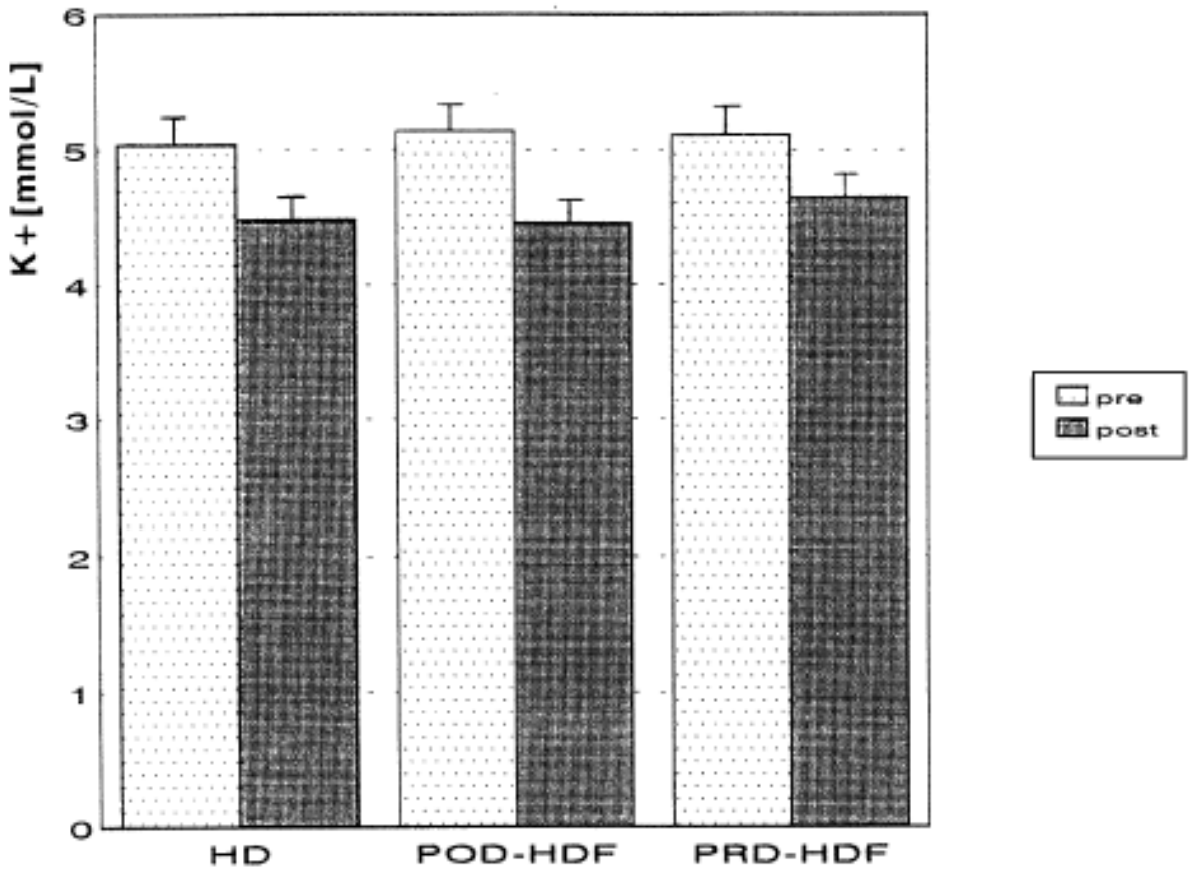
	Procedure (min)	HCO_3^- -conc. (mmol/L)	Total infusate (L)
High-Flux-HD	241 ± 43	32.0 ± 1.5	-
Online-PRD-HDF	246 ± 43	32.3 ± 1.1	40.6 ± 8.7
Online-POD-HDF	242 ± 42	33.2 ± 1.5	17.1 ± 4.3

Plasma-pH and -bicarbonate
pre/post HD and On-Line HDF with pre- and postdilution



Int J Artif Organs 1998; 21:321-327

Plasma potassium concentration
pre and post HD and On-Line-HDF with pre- and postdilution
(10 patients, 50 treatments/mode; dialysate K^+-conc. 4 mmol/L)



Int J Artif Organs 1998; 21:321-327

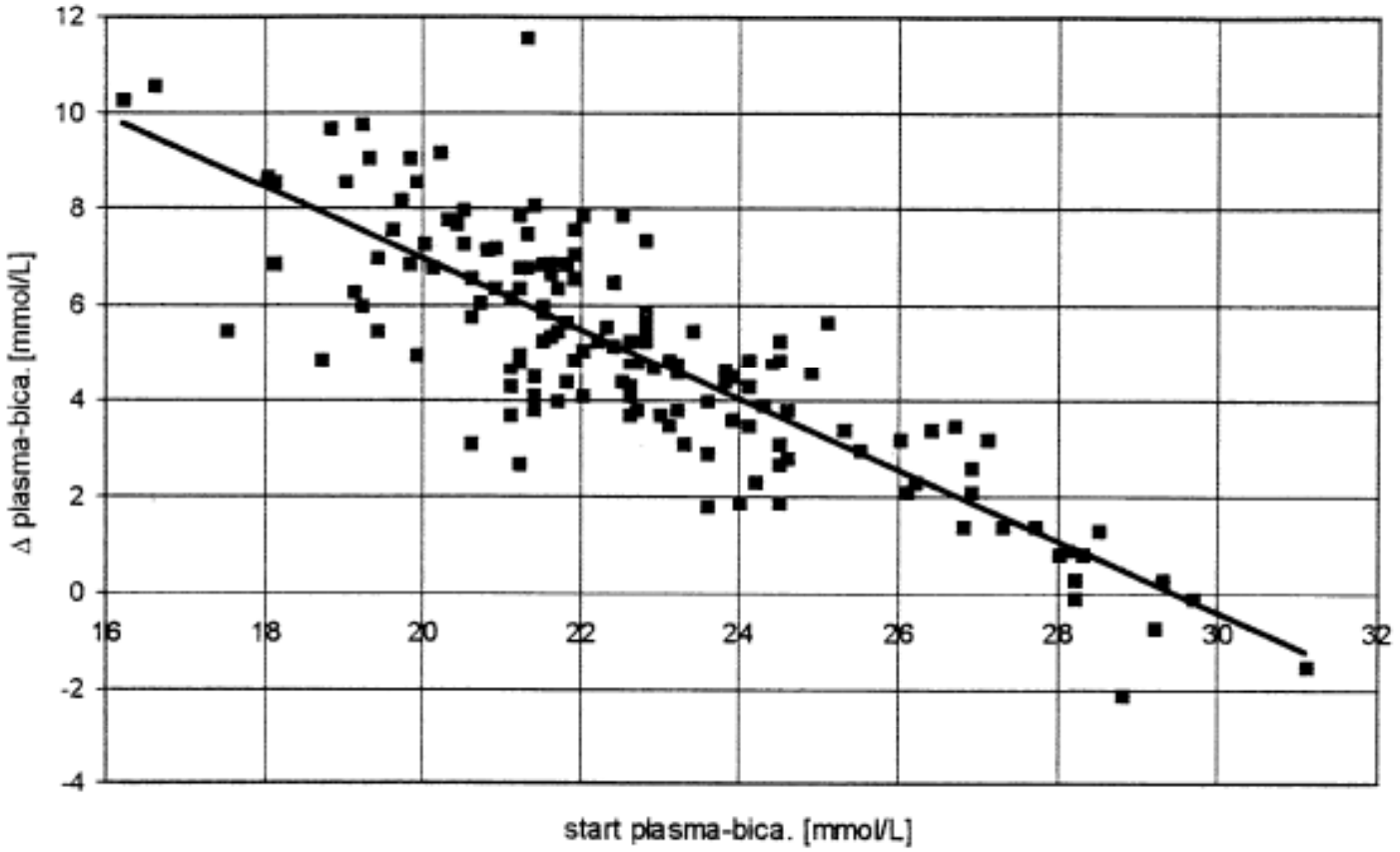
TABLE II - MEAN ACID-BASE PARAMETERS BEFORE AND AFTER TREATMENT WITH HD, ON-LINE-POD-HDF AND ON-LINE-PRD-HDF (mean ± SD; N = 50)

Parameter →	pH		HCO_3^- (mmol/L)		(mmol/L) BE	
Procedure ↓	pre	post	pre	post	pre	post
High-Flux-HD	**7.393** ± 0.043	**7.466** ± 0.043	**22.35** ± 2.85	**27.58** ± 1.59	**-1.6** ± 2.6	**4.4** ± 1.7
On-Line-PRD-HDF	**7.397** ± 0,037	**7.464** ±0.038	**23.05** ± 2.91	**27.59** ± 1.55	**-0.9** ± 2.6	**4.4** ± 1.5
On-Line-POD-HDF	**7.391** ± 0.038	**7.466** ± 0.037	**23.05** ± 2.77	**27.90** ± 1.50	**-1.1** ± 2.7	**4.7** ± 1.4

Int J Artif Organs 1998; 21:321-327

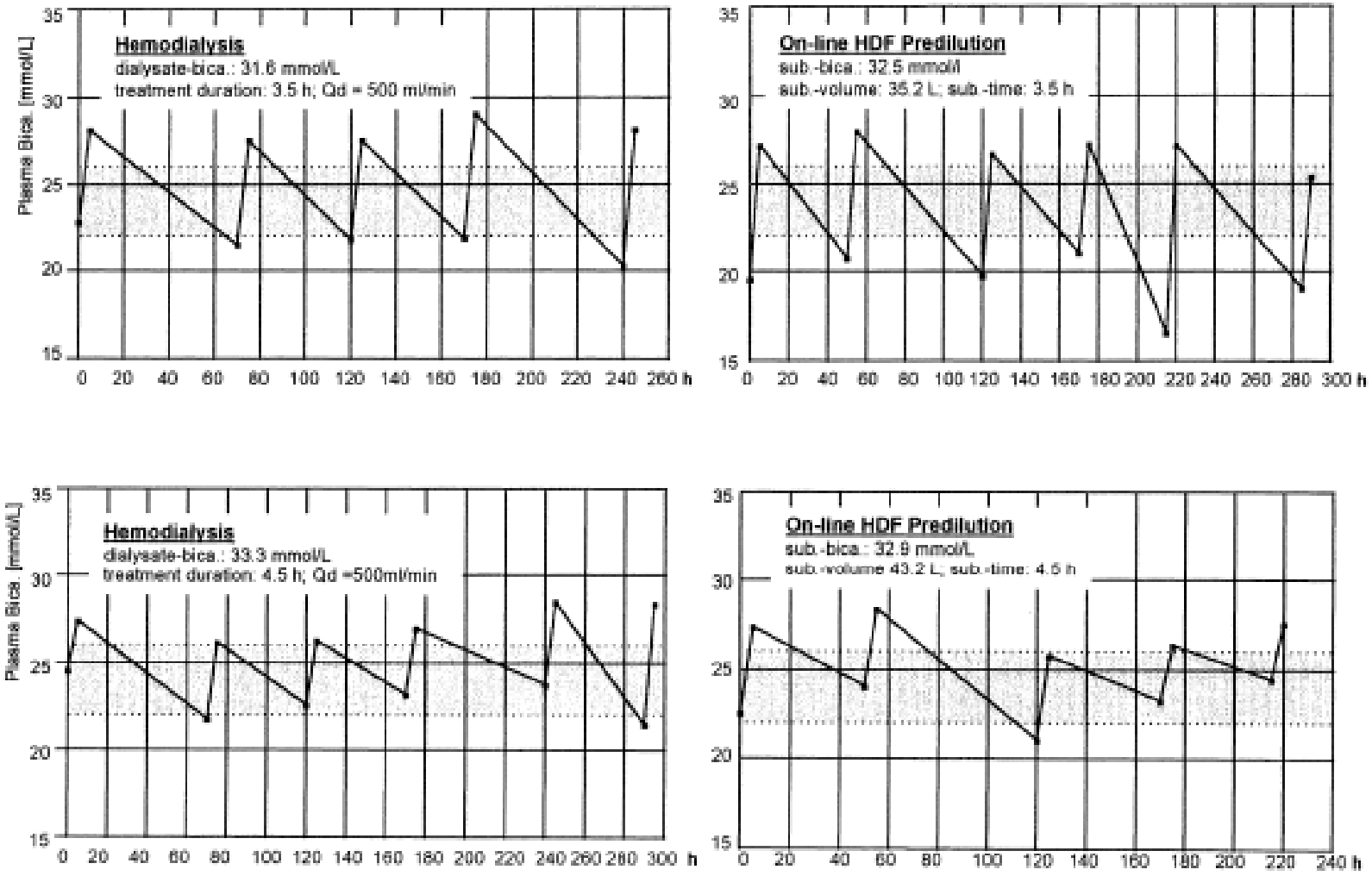
Increase of the plasma-bicarbonate concentration *vs.* start value

(HD, Online HDF POD and PRD, n = 150, corr. coeff. = -0.84)



Int J Artif Organs 1998; 21:321-327

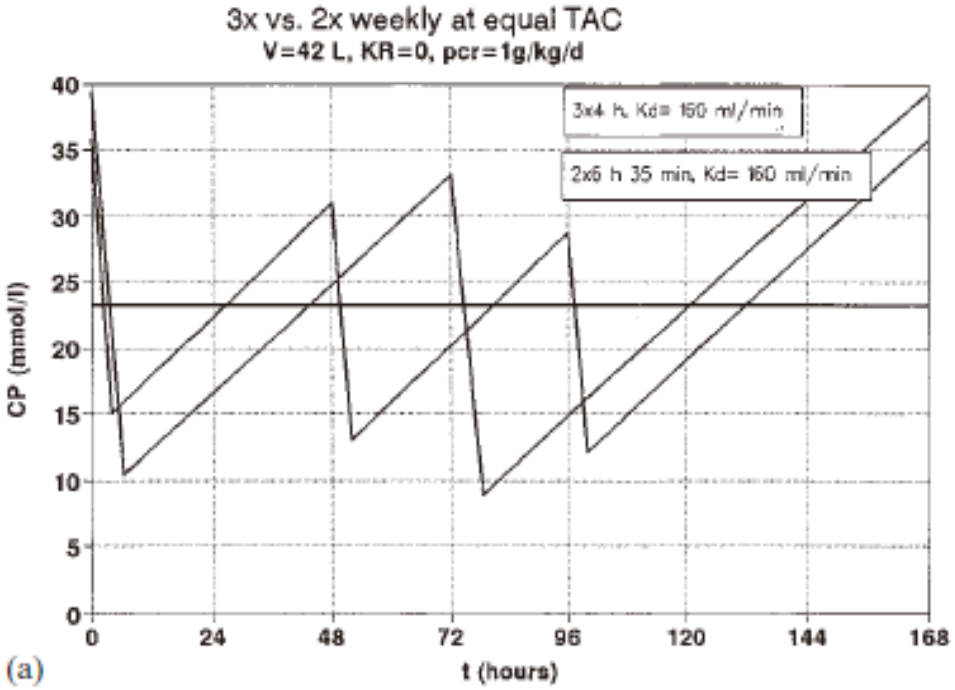
Time course of the plasma-bicarbonate concentration with hemodialysis and predilution on-line-HDF



Int J Artif Organs 1998; 21:321-327

Physiology ≈ **stability of the 'millieu interieur'**

≈ **homeostasis, steady state**



Nephrol Dial Transplant 13 [Suppl 6]: 74–78, 1998

The patient's body is never in a normal state; it is in an abnormal state, **both before *and after dialysis*. …..UNPHYSIOLOGIC**

Kjellstrand CM, Evans RL, Petersen RJ, Shideman JR, von Hartitzsch B, Buselmeier TJ
***Kidney Int* 1975; Suppl 2:30-34**

The Un-Physiology Hypothesis

"Side effects seemed particularly common in patients who experience great swings in **body weight**, **urea (osmolality)**, and **potassium**, and who had — as a consequence of their large fluid load — severe hypertension."

When dialysis is over, the patient's **serum potassium** level is below normal and the patient is **alkalotic** and short of **fluid** in the vascular space.

Nephrol Dial Transplant (1998) 13 [Suppl 6]: 74–78

Nephrology
Dialysis
Transplantation

Quantification of dialysis unphysiology

F. Lopot and A. Válek[1]

General University Hospital, Departr

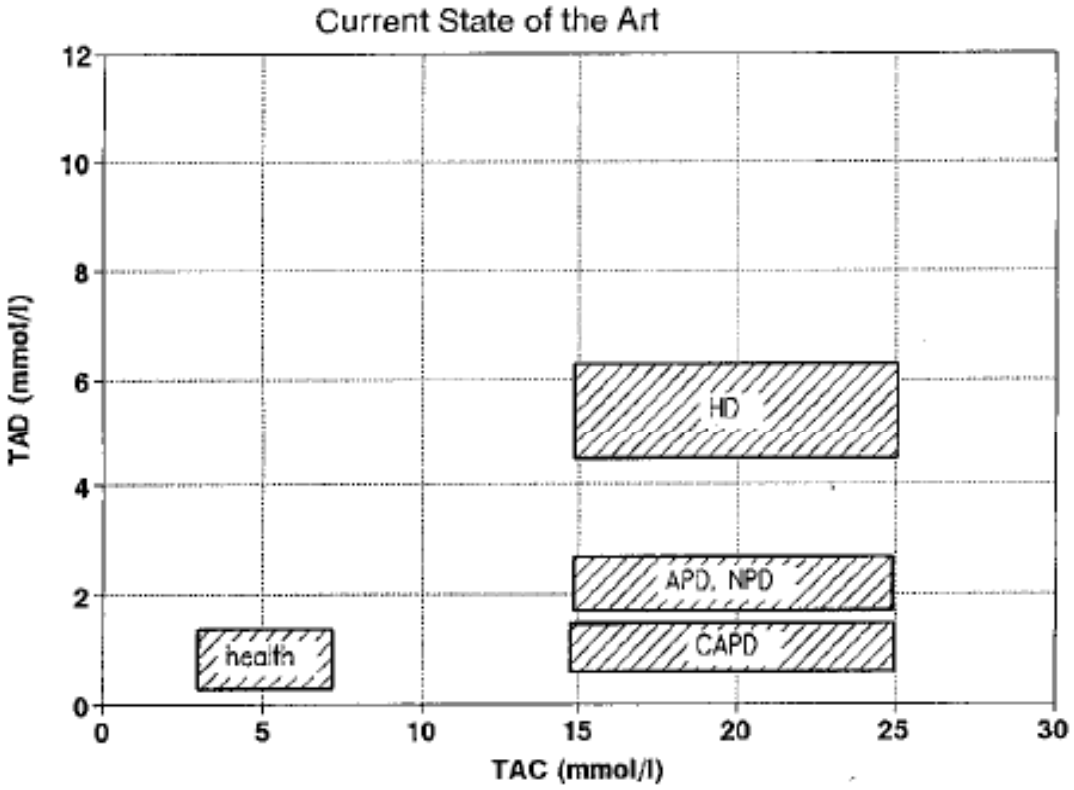


Fig. 6. TAC/TAD representation of currently used renal replacement therapies and health.

The International Journal of Artificial Organs / Vol. 31 / no. 3, 2008 / pp. 237-243

Artificial Kidney and Dialysis

Switching from three times a week to short daily online hemodiafiltration: Effects on acid-base balance

J. HERNÁNDEZ-JARAS, E. TORREGROSA DE JUAN, R. PONS-PRADES, A. RÍUS-PERIS, M.A. FENOLLOSA-SEGARRA

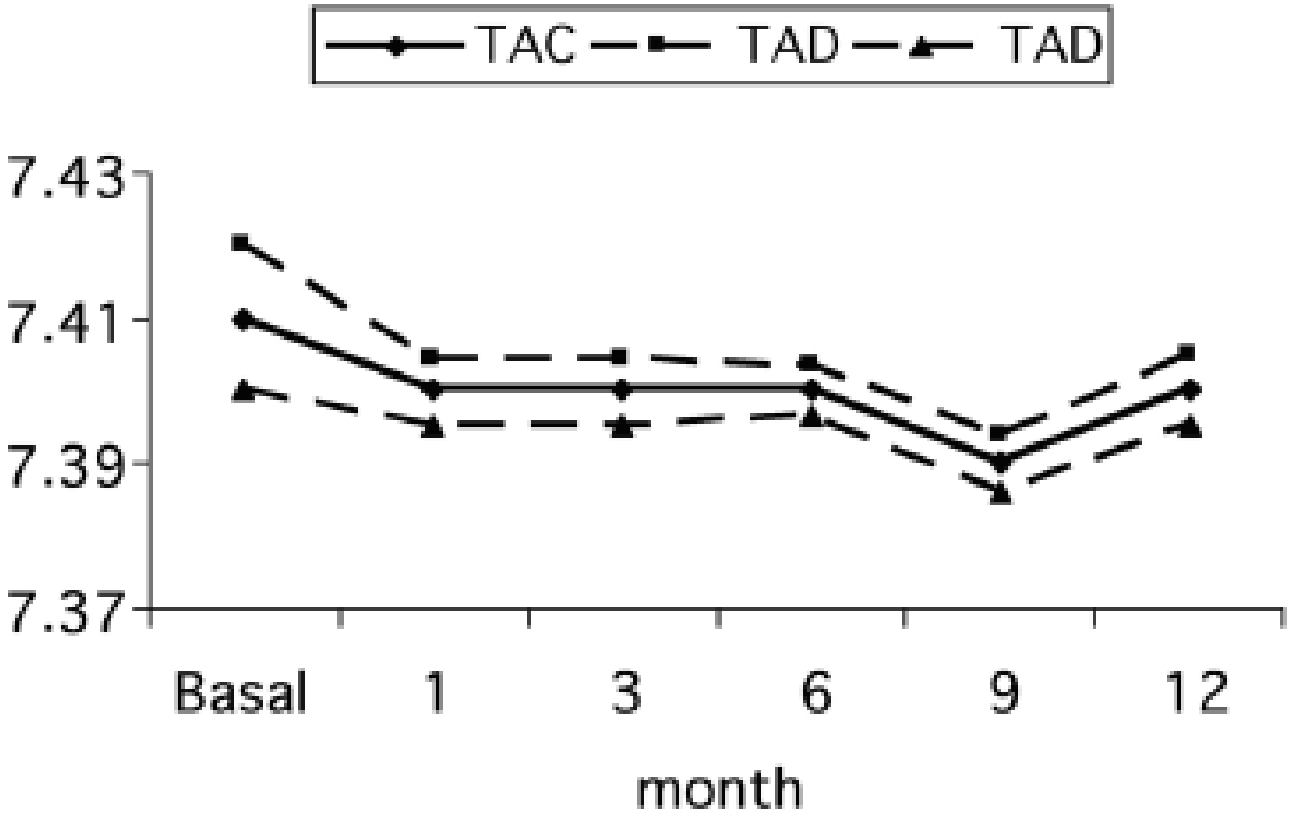
Department of Nephrology, Hospital General, Castellón - Spain

TABLE II - ACID-BASE VALUES: COMPARISON DURING THE STUDY PERIOD

	Baseline	Month 1	Month 3	Month 6	Month 9	Month 12	p Value
pH pre-HDF	7.37 ± 0.03	7.39 ± 0.03	7.38 ± 0.04	7.39 ± 0.03	7.37 ± 0.04	7.37 ± 0.04	n.s.
pH post-HDF	7.46 ± 0.02*	7.42 ± 0.04*	7.42 ± 0.03*	7.42 ± 0.02†	7.41 ± 0.04†	7.43 ± 0.04*	<0.01
pCO_2 pre-HDF (mmHg)	39.3 ± 4.1	39.5 ± 4.9	41.1 ± 3.7	40.3 ± 3.3	40.9 ± 4.8	39.8 ± 4.6	n.s.
pCO_2 post-HDF (mmHg)	37.6 ± 2.6	39.1 ± 4.4	41.2 ± 3.8	40.4 ± 5.7	41.3 ± 7.7	38.4 ± 4.0	n.s.
HCO_3^- pre-HDF (mEq/L)	23.3 ± 2.3	24.3 ± 2.1	25 ± 2	25 ± 2.4	24.4 ± 2.3	23.8 ± 2.5	n.s.
HCO_3^- post-HDF (mEq/L)	27.4 ± 1.5*	26.2 ± 1.9*	27.4 ± 1.3*	26.7 ± 2.3*	26.4 ± 2.5*	26.4 ± 1.5*	n.s.
BEStd pre-HDF (mEq/L)	-1.1 ± 2.2	0.12 ± 2.0	0.62 ± 2.0	0.77 ± 2.4	-0.11 ± 2.2	-0.62 ± 2.7	n.s.
BEStd post-HDF (mEq/L)	4.1 ± 1.4*	2.4 ± 1.7*	3.3 ± 1.1*	2.7 ± 1.6*	2.2 ± 1.6*	2.8 ± 1.5†	<0.01

BEStd: base excess standard; HDF: hemodiafiltration; n.s.: not significant.
*p<0.01, †p<0.05, vs. pre-HDF values.

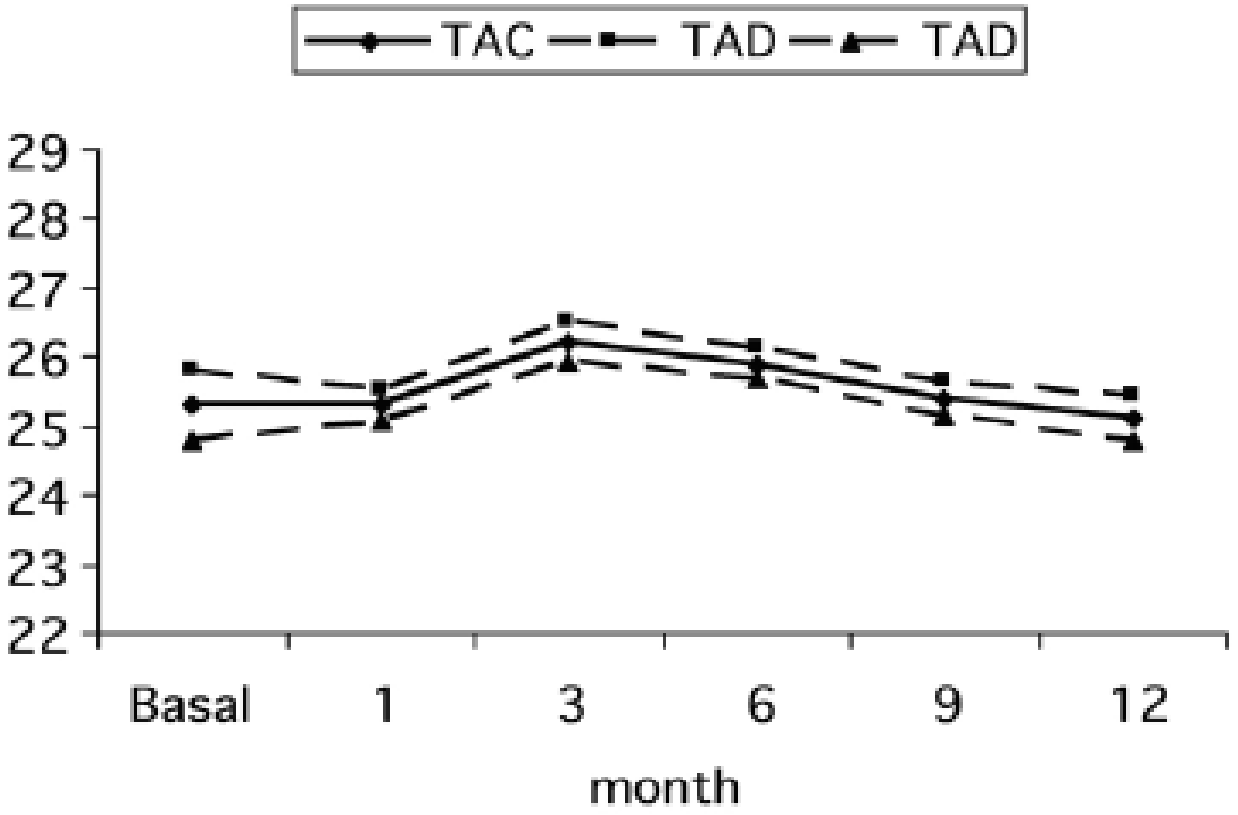
Evolution of pH time-averaged concentration (TAC) and time-averaged deviation (TAD) over months of study



TAD represents mean deviation (±) from the pHTAC.

Int J Artif Organs 2008; 31: 237 - 243

Evolution of HCO_3^- time-averaged concentration (TAC) and time-averaged deviation (TAD) over months of study



TAD represents mean deviation (±) of plasma concentration from the HCO_3^- TAC.

Int J Artif Organs 2008; 31: 237 - 243

Switching from three times a week to short daily online HDF

TABLE III - CATIONS AND ANIONS: COMPARISON DURING THE STUDY PERIOD

(mEq/L)	Baseline	Month 1	Month 3	Month 6	Month 9	Month 12	p Value
Na^+ pre-HDF	138.9 ± 3.3	139.9 ± 3.4	139.7 ± 3.3	139.3 ± 2.6	139.9 ± 3.3	140.5 ± 2.7	n.s.
Na^+ post-HDF	137.7 ± 3.0	138.9 ± 3.0	139.0 ± 2.4	139.2 ± 2.9	139.4 ± 2.5	139.6 ± 2.0	n.s.
K^+ pre-HDF	4.8 ± 0.4	4.5 ± 0.4	4.6 ± 0.3	4.8 ± 0.7	4.9 ± 0.5	4.6 ± 0.4	n.s.
K^+ post-HDF	3.1 ± 0.2*	3.2 ± 0.3*	3.2 ± 0.2*	3.1 ± 0.1*	3.3 ± 0.4*	3.2 ± 0.2*	n.s.
Cl^- pre-HDF	98.2 ± 3.8	98.2 ± 3.0	97.5 ± 3.0	97.0 ± 2.4	97.9 ± 1.7	97.7 ± 2.0	n.s.
Cl^- post-HDF	96.1 ± 3.5*	97.5 ± 3.1	96.7 ± 2.2	97.5 ± 1.8	97.3 ± 2.0	97.1 ± 2.0	n.s.
Lactate pre-HDF	1.0 ± 0.4	1.2 ± 0.6	1.2 ± 0.5	1.1 ± 0.4	1.1 ± 0.5	1.0 ± 0.5	n.s.
Lactate post-HDF	0.9 ± 0.4	1.1 ± 0.5	0.9 ± 0.3	1.0 ± 0.3	1.2 ± 0.5	1.0 ± 0.3	n.s.

*$p<0.01$, vs. pre-HDF values.

Int J Artif Organs 2008; 31: 237 - 243

5008

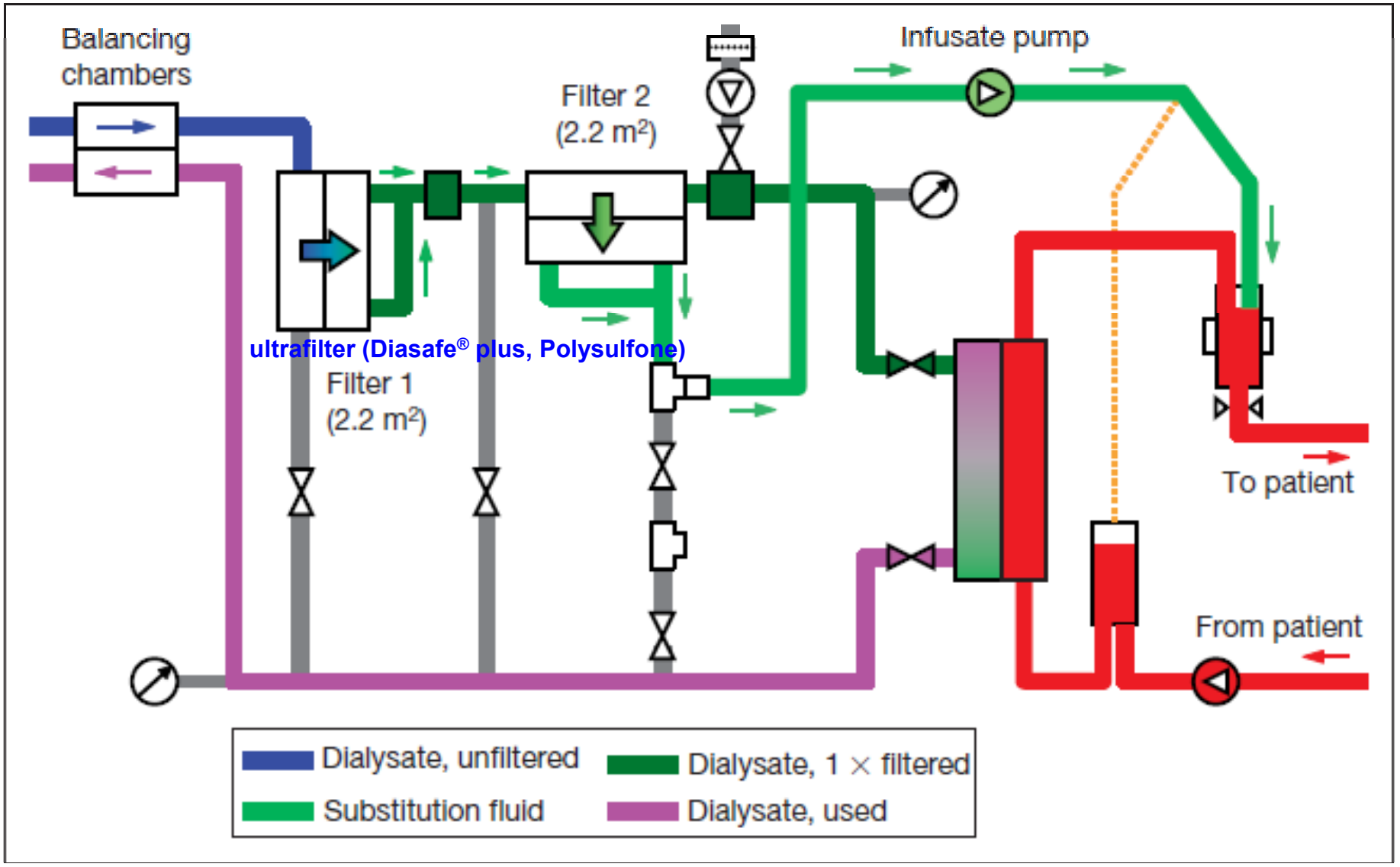
Touching Experience

Best Handling for all Users

Best Therapy for your Patients

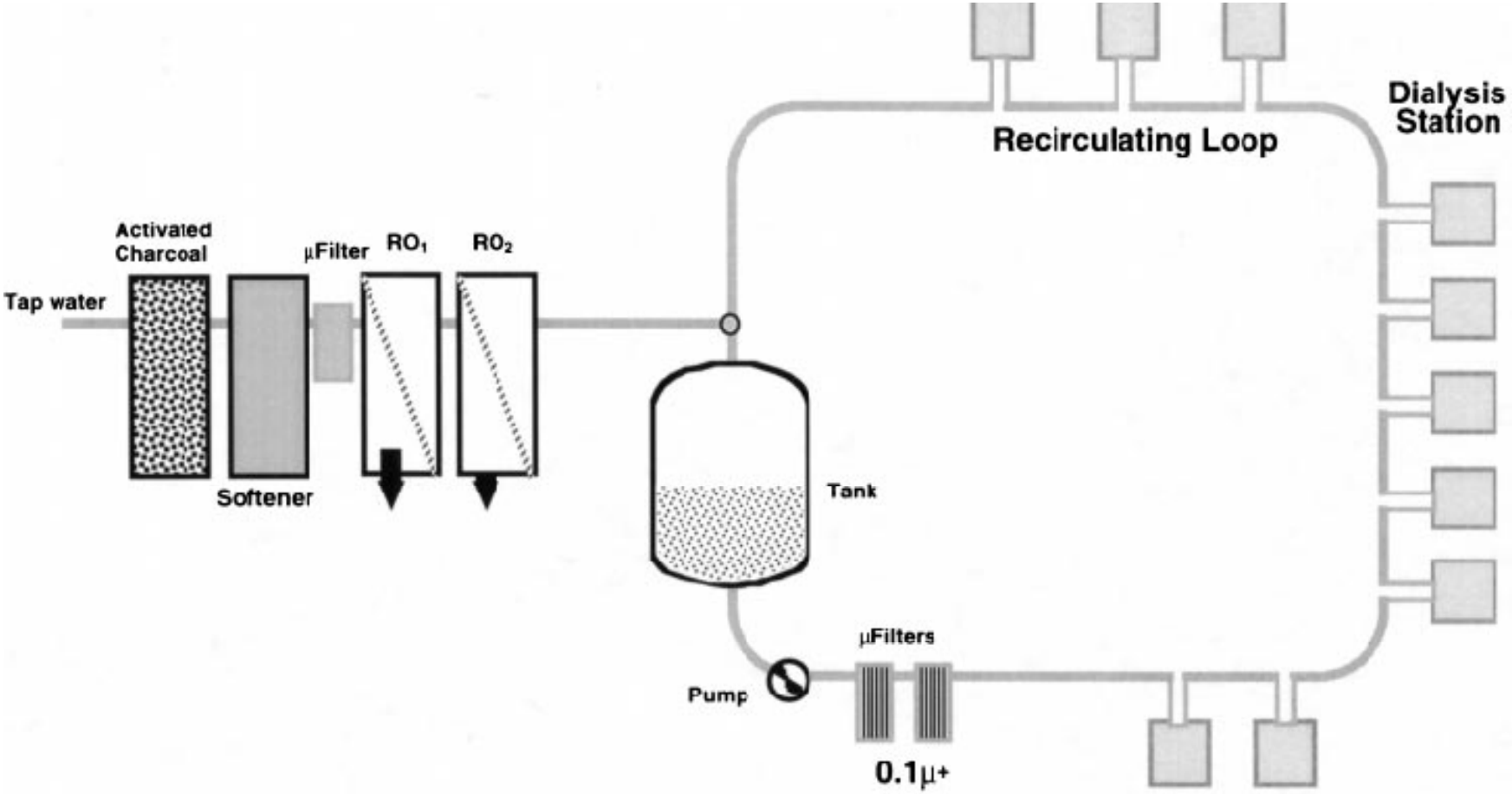
Optimal Use of Resources

FME 2-filter hemodialysis system



Redrawn from Fresenius Medical Care Online plus 7/07.03 (OP), Fresenius Medical Care, Bad Homburg, Germany (**Contrib Nephrol 158: 68-79, 2007**).

Water treatment system used to produce and deliver ultrapure water to HDF machines



A permanent circulation and microfiltration of treated water through the positively charged membrane is maintained and HDF machines are fed directly from the recirculating loop (Nephrol Dial Transplant 13 [Suppl 5]: 3–11, 1998).

Summary of our practice for online HDF

Equipment

- High-flux membranes: Helixone
- Ultrapure dialysis fluid
- Sterilizing ultrafilter as final filter
- Dialysis machine approved for online fluid preparation

Treatment variables

- Substitution: post-dilution, 30 L/session
- Blood flow: 250 – 300 mL/min
- Dialysis fluid flow rate: 500 mL/min

Organization

- Established routines for periodical evaluation of microbiological quality of water and dialysis fluid

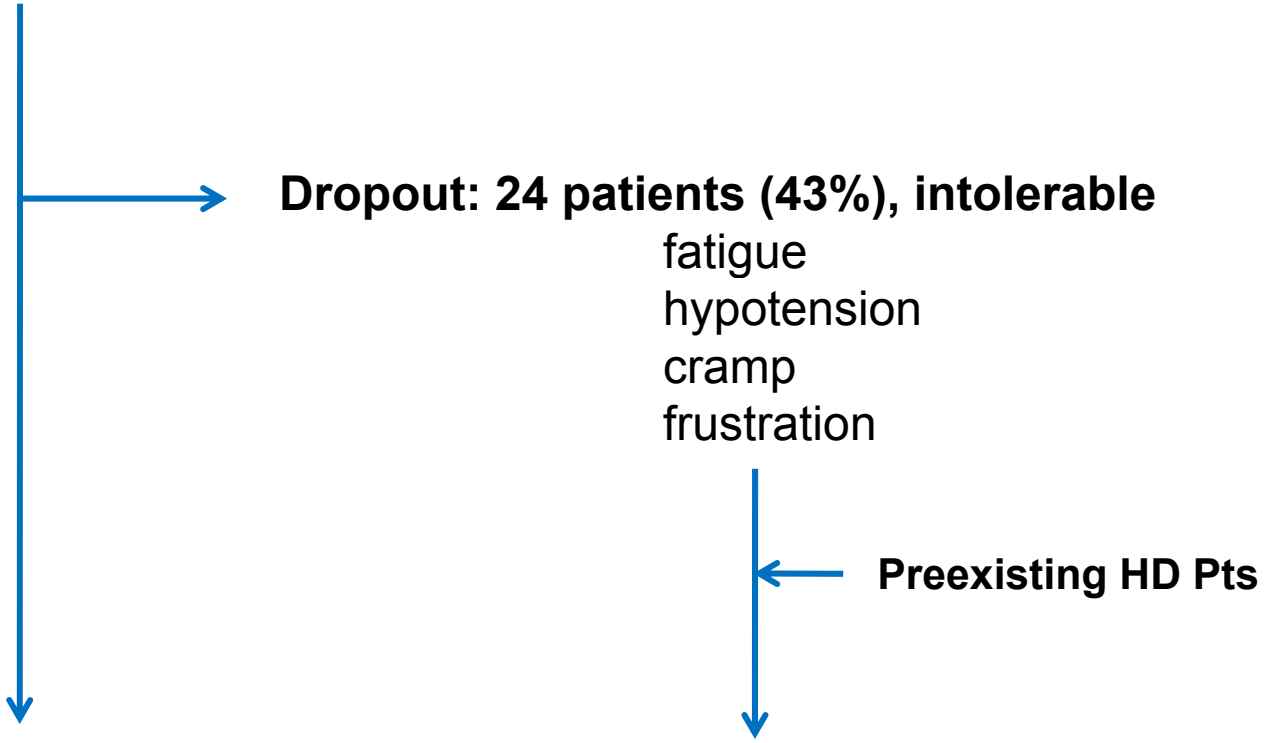
Patient assessment of quality of life based on the Kidney Disease Questionnaire

	Hemodiafiltration		High-Flux Hemodialysis		*P* (Time)	*P* (Mode)
	6 Mo	12 Mo	6 Mo	12 Mo		
Physical symptoms	3.9 ± 0.3	4.8 ± 0.3	4.3 ± 0.3	4.8 ± 0.4	<0.001	0.657
Fatigue	4.6 ± 0.3	4.9 ± 0.4	4.7 ± 0.3	4.9 ± 0.3	0.083	0.910
Depression	5.6 ± 0.2	5.8 ± 0.2	5.6 ± 0.3	5.6 ± 0.3	0.086	0.684
Relationships	5.1 ± 0.3	5.2 ± 0.3	5.1 ± 0.3	5.1 ± 0.3	0.077	0.904
Frustration	5.3 ± 0.3	5.2 ± 0.4	5.3 ± 0.3	5.4 ± 0.4	0.648	0.851

[a] Each dimension of the Kidney Disease Questionnaire is scored on a seven-point scale, in which 1 is the worst possible score and 7 is the best possible score. *P* values represent the significance of changes with time (Time) or between hemodiafiltration and high-flux hemodialysis (Mode).

J Am Soc Nephrol 11: 2344–2350, 2000

Ol HDF was applied to a total of 56 patients since Sep. 2008.



Demographic features

	HFHD (n = 49)	**ol-HDF** (n = 27)
Male/Female	26/23	17/10
Mean Age (yr)	54.2	53.7
Duration of dialysis (mo) *	**75 ± 120**	**145 ± 95**
BMI (kg/m^2)	22.7 ± 3.7	22.0 ± 3.0
Underlying disease *		
DM	**22**	3
HTN	5	**7**
CGN	9	4
Others	2	0
Unknown	11	13

Continuous values are mean ± SD.

* $P < 0.01$, HFHD *vs.* on-HDF

Predialysis values

	HFHD (n = 49)	**ol-HDF** (n = 27)
Glucose (mg/dL)	126 ± 74	92 ± 29
Cholesterol (mg/dL)	153 ± 31	147 ± 36
Triglyceride (mg/dL)	114 ± 69	96 ± 41
Hb (g/dL)	10.2 ± 1.1	10.4 ± 1.3
Albumin (g/dL)	4.17 ± 0.33	4.24 ± 0.28
BUN (mg/dL)	64 ± 20	71 ± 20
Creatinine (mg/dL) *	**8.7 ± 2.3**	**10.7 ± 2.3**
KT/Vurea, sp	1.5 ± 0.3	1.6 ± 0.3
Intact-PTH (pg/mL) *	**227 ± 188**	**316 ± 177**
SAP (IU/L)	85 ± 32	91 ± 53
Uric acid (mg/dL)	6.9 ± 1.3	7.3 ± 1.2

Values are mean ± SD. * $P < 0.05$, HFHD *vs.* on-HDF by Mann-Whitney U test

Pre- and post-dialysis values (I)

	HFHD (n = 49)	**oI-HDF** (n = 27)
Pre-HD Na^+ (mEq/L)	137 ± 3	138 ± 2
Post-HD Na^+ (mEq/L)	134 ± 3	134 ± 2
Δ Na^+ (mEq/L), mean *	**- 2.4**	**- 4.1**
Pre-HD K^+ (mEq/L) *	4.7 ± 0.9	5.1 ± 0.7
Post-HD K^+ (mEq/L)	3.2 ± 0.4	3.3 ± 0.4
Δ K^+ (mEq/L) *	**- 1.5**	**- 1.8**
Pre-HD Cl^- (mEq/L)	98 ± 4	98 ± 3
Post-HD Cl^- (mEq/L)	94 ± 3	93 ± 2
Δ Cl^- (mEq/L)	**- 3.7**	**- 5.3**
Pre-HD tCO_2 (mEq/L)	22.1 ± 3.9	21.7 ± 3.5
Post-HD tCO_2 (mEq/L)	26.7 ± 2.9	26.9 ± 2.9
Δ tCO_2 (mEq/L)	**+ 4.5**	**+ 5.1**

Values are mean ± SD. * $P < 0.05$, HFHD *vs.* on-HDF by Mann-Whitney U test

Dialysate concentrations

	Prescribed	Measured (n = 12) *
Na^+ (mEq/L)	138	137 ± 2
K^+ (mEq/L)	1.97	1.98 ± 0.1
Cl^- (mEq/L)	108	102 ± 2
HCO_3^- (mEq/L)	32.5	32.4 ± 1.6

* Values are mean ± SD.

Pre- and post-dialysis values (II)

	HFHD (n = 49)	**oI-HDF** (n = 27)
Pre-HD Ca (mg/dL)	8.9 ± 0.6	8.8 ± 0.7
Post-HD Ca (mg/dL)	10.0 ± 0.7	10.1 ± 0.8
Δ **Ca** (mg/dL), mean	+ 1.1	+ 1.3
Pre-HD Phosphorus (mg/dL) *	**5.1 ± 1.5**	**6.2 ± 1.3**
Post-HD Phosphorus (mg/dL)	2.2 ± 0.7	2.3 ± 0.7
Δ **Phosphorus** (mg/dL) *	**- 2.8**	**- 3.9**
Pre-HD β_2-microglobulin (mg/L)	23 ± 7	23 ± 1
Post-HD β_2-microglobulin (mg/L) *	**11 ± 4**	**8 ± 3**
Δ **β_2-microglobulin** (mg/L) *	**- 12**	**- 16**

Values are mean ± SD. * $P < 0.05$, HFHD *vs.* on-HDF by Mann-Whitney U test

Summary: Electrolyte profiles in online HDF

1. Pre- and post-dialysis serum concentrations of **sodium** and **potassium** are not different between online HDF and high-flux HD.

2. **Differences between pre- and post-dialysis serum concentrations of sodium and potassium** may be larger in online HDF than in high-flux HD.

3. Whether acid-base profile and **serum bicarbonate** concentrations are different between online HDF and high-flux HD is not clear.

4. Although more **phosphate** may be removed by online HDF, predialysis serum calcium and phosphorus concentration would not be significantly affected.