Ultrafiltration, Intradialytic Hypotension & Mortality

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2ième Symposium Infirmier romand en Néphrologie

Disclosure

Speaker name: Prof. Bernard Canaud

☐ I have the following potential conflicts of interest to report:

☐ Consulting

☒ **Employment in industry (FMC)**

☐ Shareholder in a healthcare company

☐ Owner of a healthcare company

☐ Other(s)

☐ I do not have any potential conflict of interest

Outlook of the Presentation

1. Sodium & fluid volume homeostasis in CKD5 HD patient
   - Basics of physiology – Challenges for nephrologist & care giver
2. Intradialytic hypotension:
   - Definition – Frequency – Causes – Consequences
3. Sodium & fluid management in HD
   - Diffusive/Convective Na
   - Ultrafiltration
4. Preventing intradialytic hypotension
   - Means: diet, residual kidney function, hemodialysis, time
   - Stepwise approach
5. Take home message

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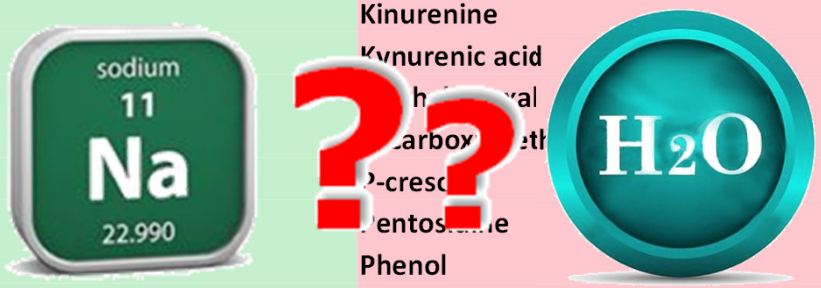
Uremic Toxins
Sodium and Fluid Are Forgotten

Small water soluble solutes *< 500 Daltons (n = 45)*	Protein-bound solutes *500 - 22000 Daltons (n = 25)*	Middle molecules *> 500 Daltons (n = 22) > 12 Daltons (n = 12)*
Asymmetric dimethylarginine	3-Deoxyglucosone	Adrenomedullin
Benzylalcohol	Carboxy-Methyl-Propyl-Furanpropionic Acid	Atrial natriuretic peptide
ß-Guanidinopropionic acid	Fructoselysine	ß2-Microglobulin
ß-Lipotropin	Glyoxal	ß-Endorphin
Creatinine	Hippuric acid	Cholecystokinin
Cytidine	Homocysteine	Clara cell protein
Guanidine	Hydroquinone	Complement factor D
Guanidinoacetic acid	Indole-3-acetic acid	Cystatin C
Guanidinosuccinic acid	Indoxyl sulfate	Degranulation inhibiting protein I
Hypoxanthine	Kinurenine	Delta-sleep-inducing peptide
Malondialdehyde	Kynurenic acid	Endothelin
Methylguanidine	[illegible]	Hyaluronic acid
Myoinositol	[illegible]	Interleukin 1ß
Orotic acid	[illegible]	Interleukin 6
Orotidine	[illegible]	Kappa-Ig light chain
Oxalate	Phenol	Lambda-Ig light chain
Pseudouridine	P-OHhippuric acid	Leptin
Symmetric dimethylarginine	Quinolinic acid	Methionine-enkepahlin
Urea	Spermidine	Neuropeptide Y
Uric acid	Spermine	Parathyroid hormone
Xanthine		Retinol Binding Protein
		Tumor Necrosis Factor Alpha

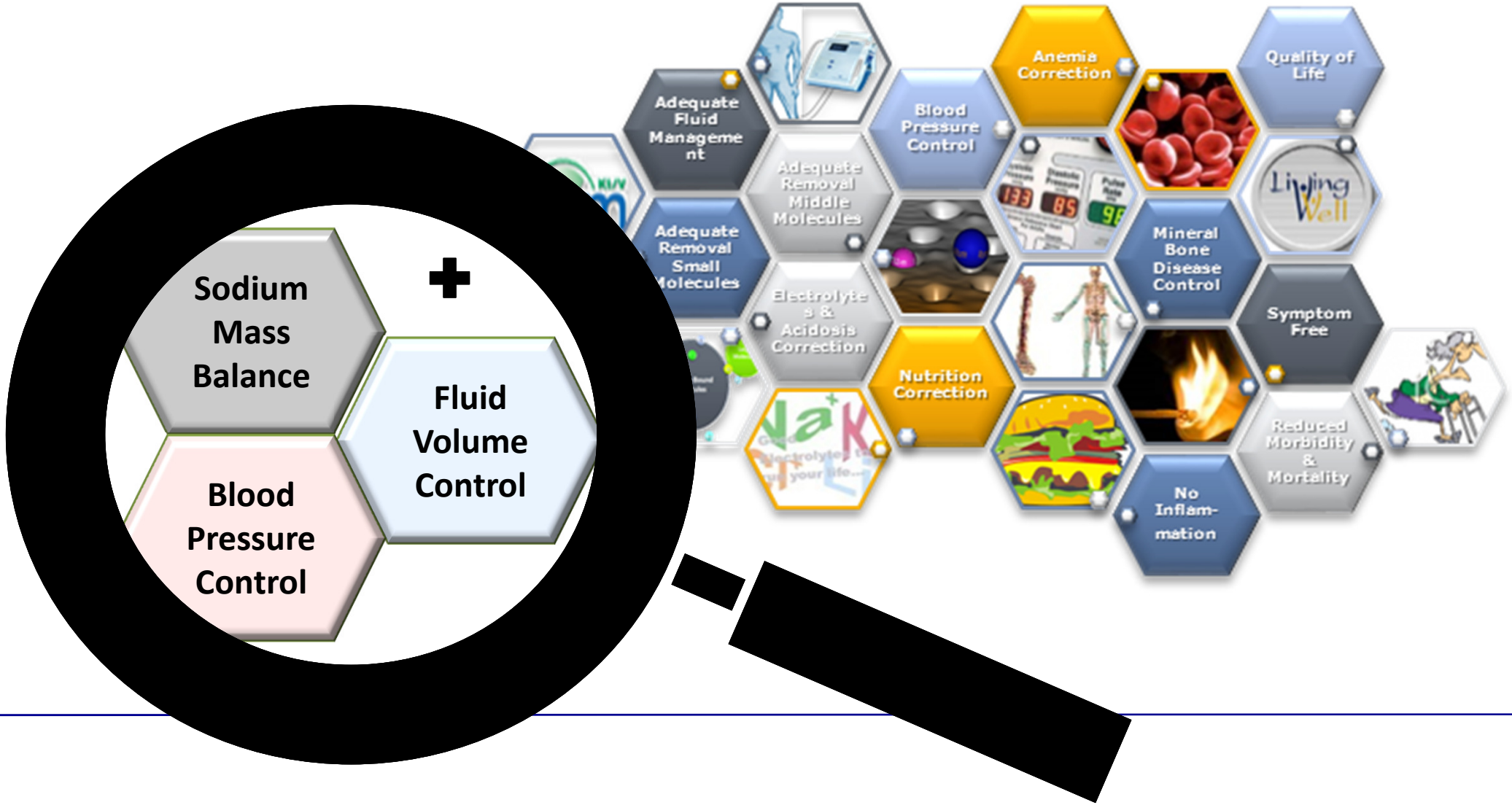


European Uremic Toxin Work Group of the ESAO

Vanholder R. et al New insights in uremic toxins. *Kidney Int*, 2003, 63; 84: S6–S10

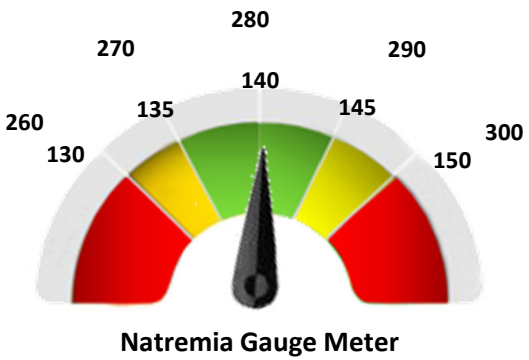
Renal Replacement Therapy Adequacy

Na Mass Balance, Fluid Control & Blood Pressure: Neglected Component



Sodium Mass Balance in Normal Subject

Sodium Homeostasis – Zero Balance



Dietary Intake
100 mM/day

ECF Na^+
2500mM
(70%)

ICF Na^+
70mM
(2%)

TransCF Na^+
1500 mM
(30%)

Skin Na^+
??

Osmotic-Na

1500mM (30%)

Non-Osmotic-Na

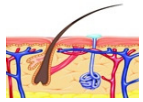
Na glycosaminoglycans

XXL mM (X%)

Normal Plasma [Na+] 140±3 mM/L

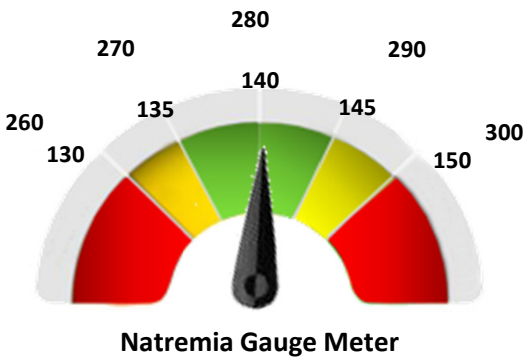
Stool Output
8 mM/day

Urinary Output
92 mM/day



Sodium Mass Balance in Hemodialysis Patient

Restore Sodium Homeostasis



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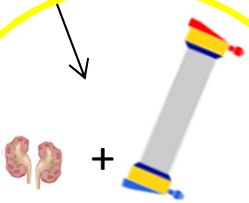
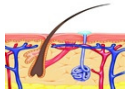


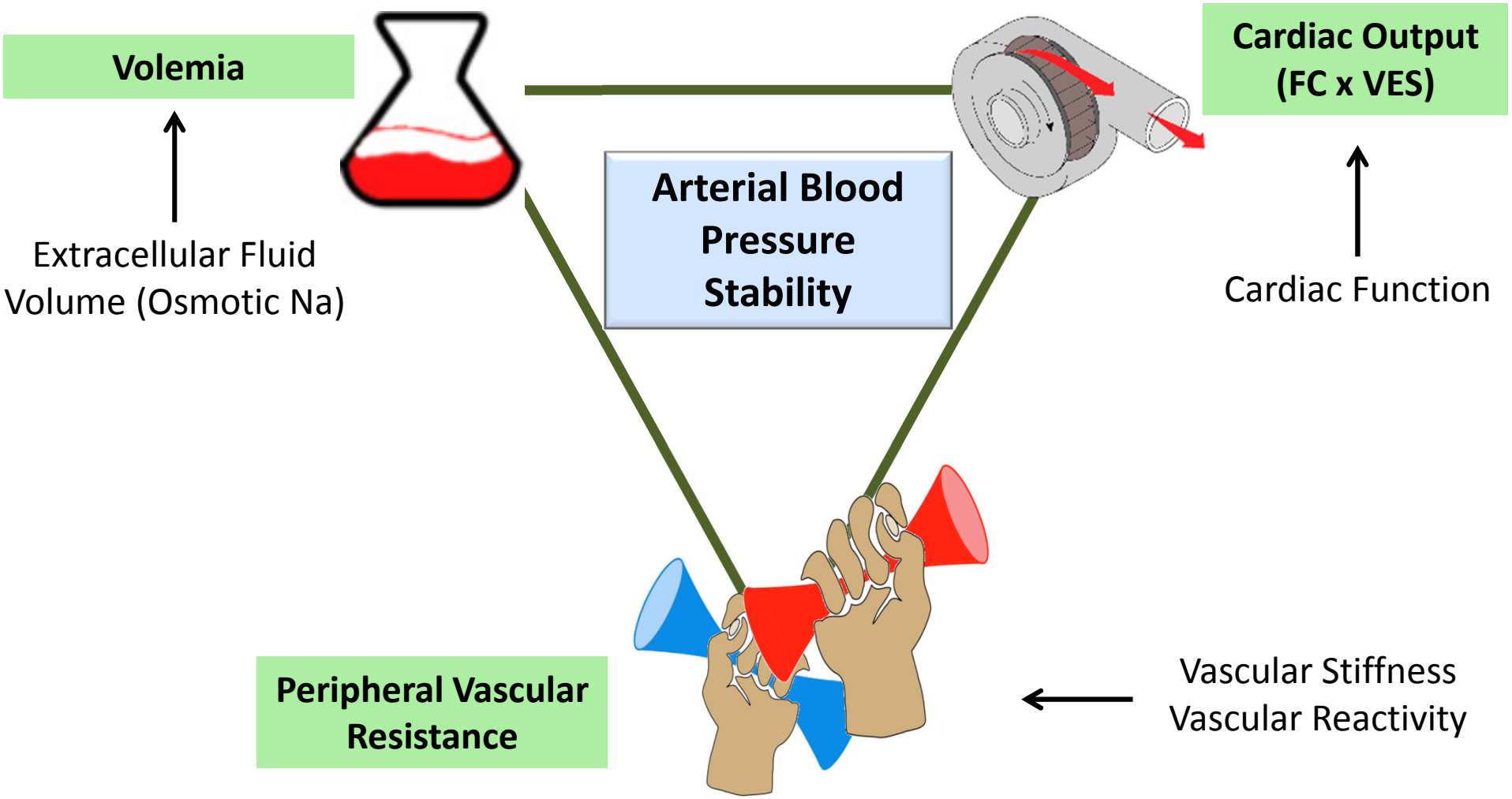
Dialysis Output
184 mM/48hr



XXL mM (X%)

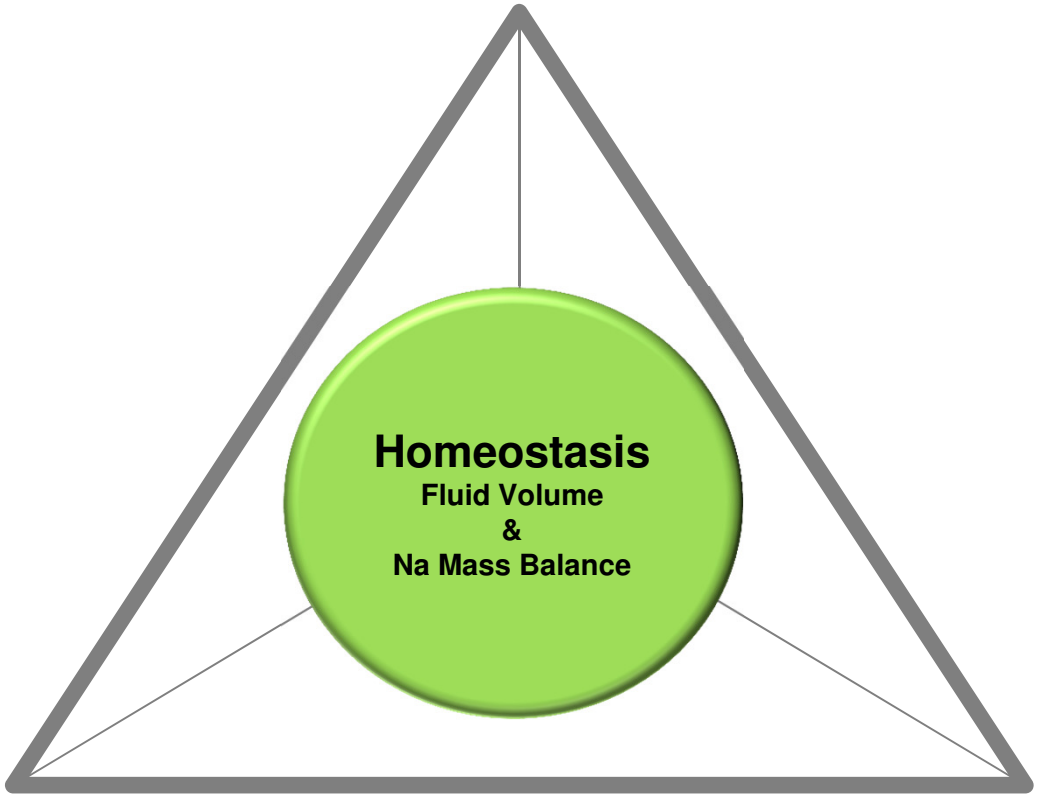
Arterial Blood Pressure Equilibrium

Mechanistic Approach



Management of Na Mass Balance & Fluid Volume
'Challenging Situation' with Intermittent Treatment

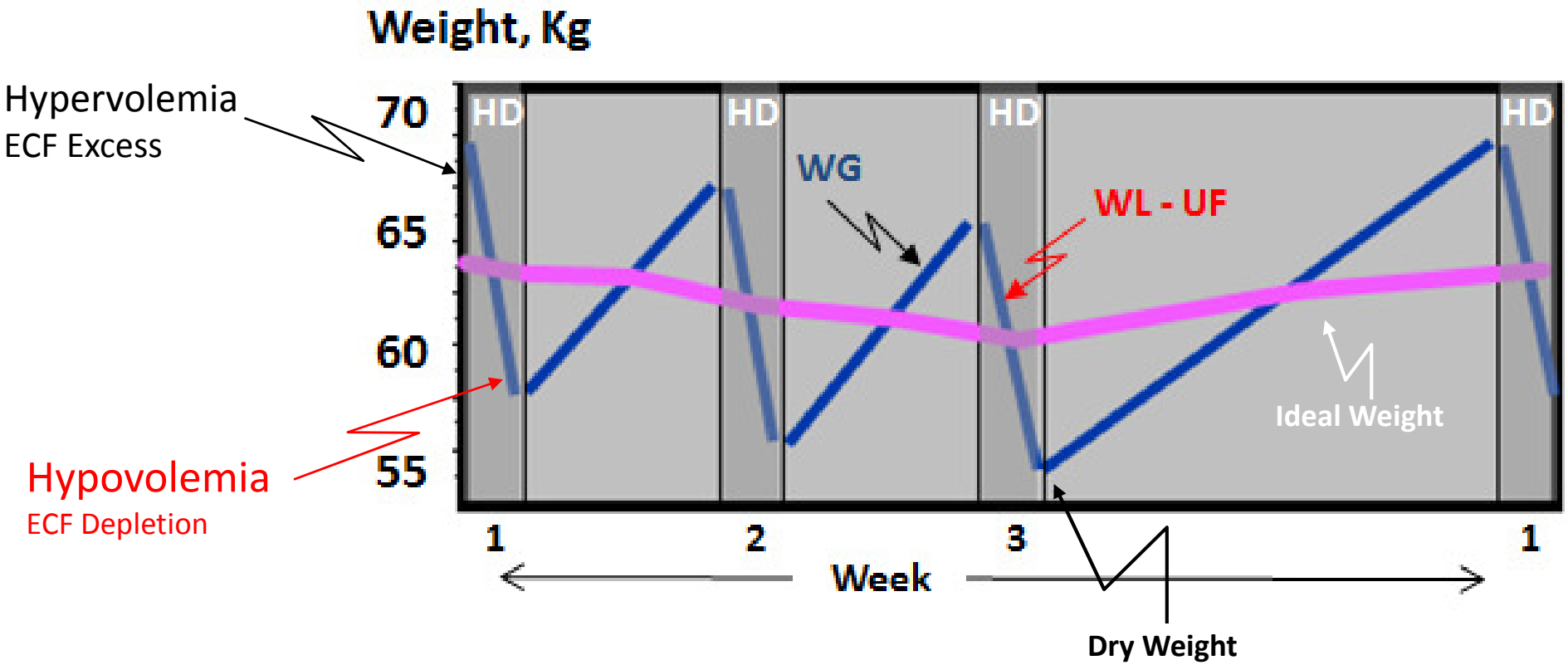
Na & Fluid Mass Balance
Extracellular Volume (volemia)



Osmolality Change

Blood Pressure

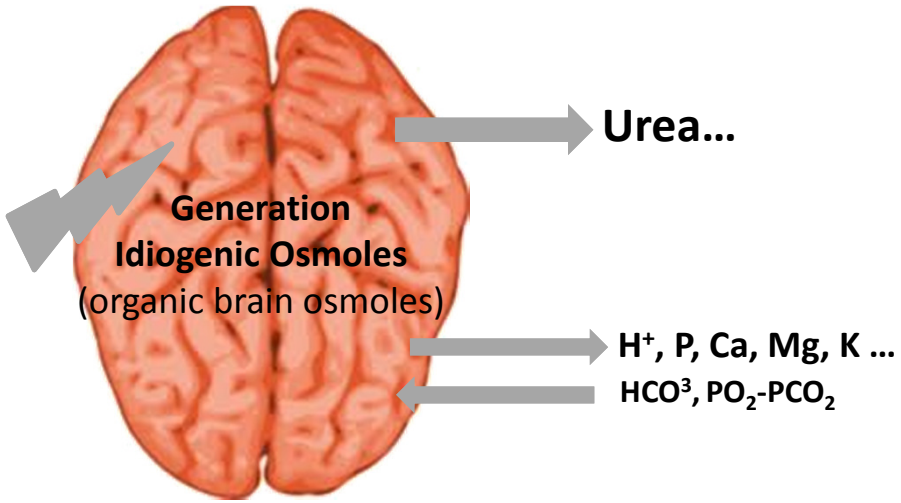
Weight Changes During HD Cycles



Osmolality Changes During HD Cycles
Brain Consequences

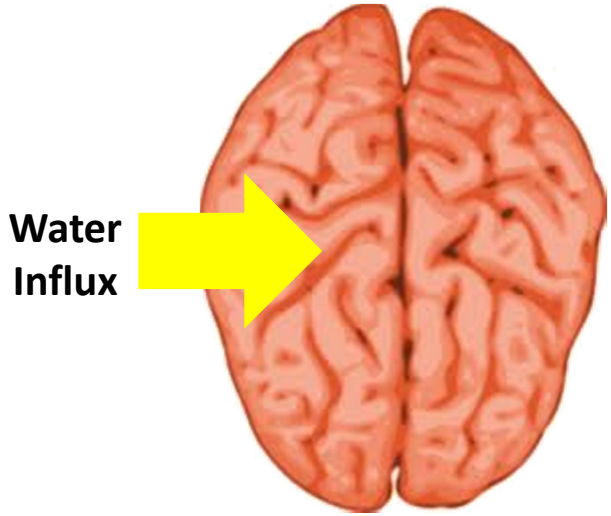
Disequilibrium Syndrome = osmolality, water shift and brain changes

Osmolality Changes
ECF/CSF/ICF



Brain during Hemodialysis

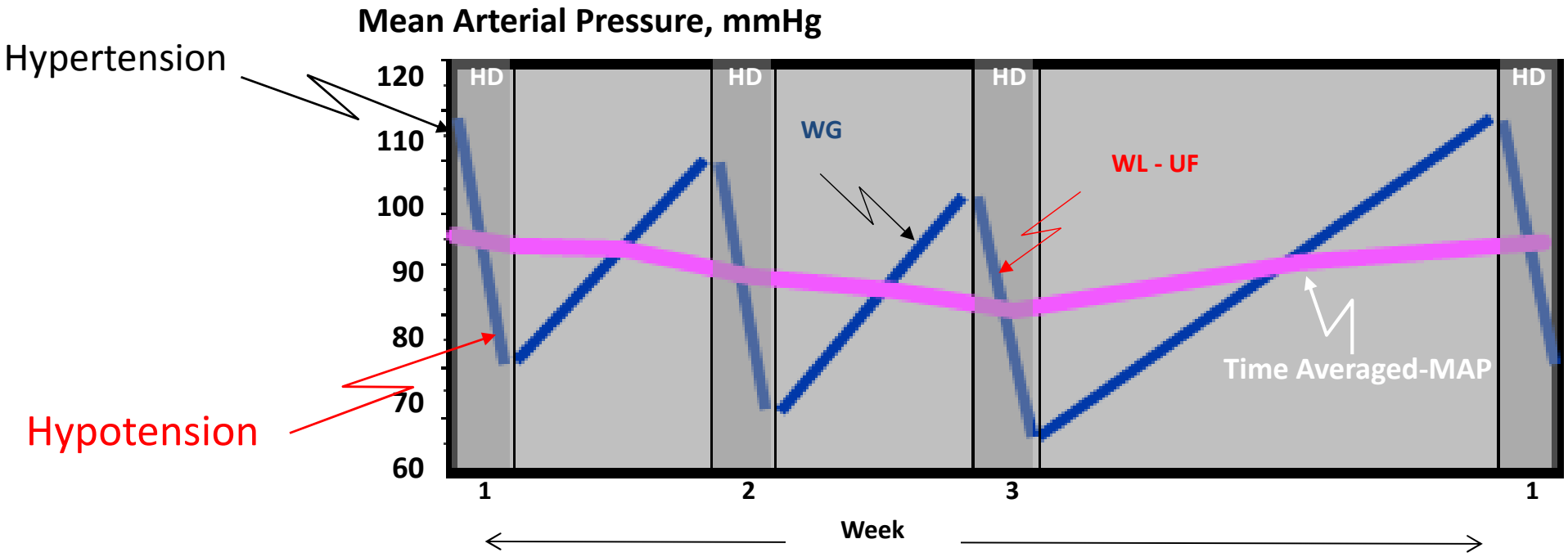
Osmolality Changes
Water Shift



Brain Edema

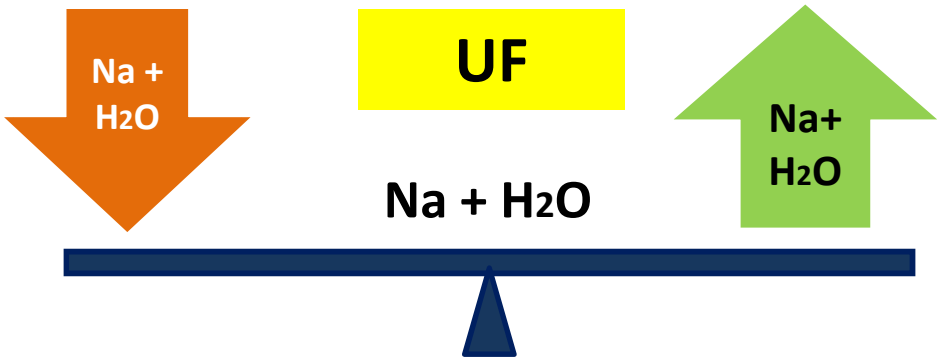
Arterial Blood Pressure Changes During HD Cycles

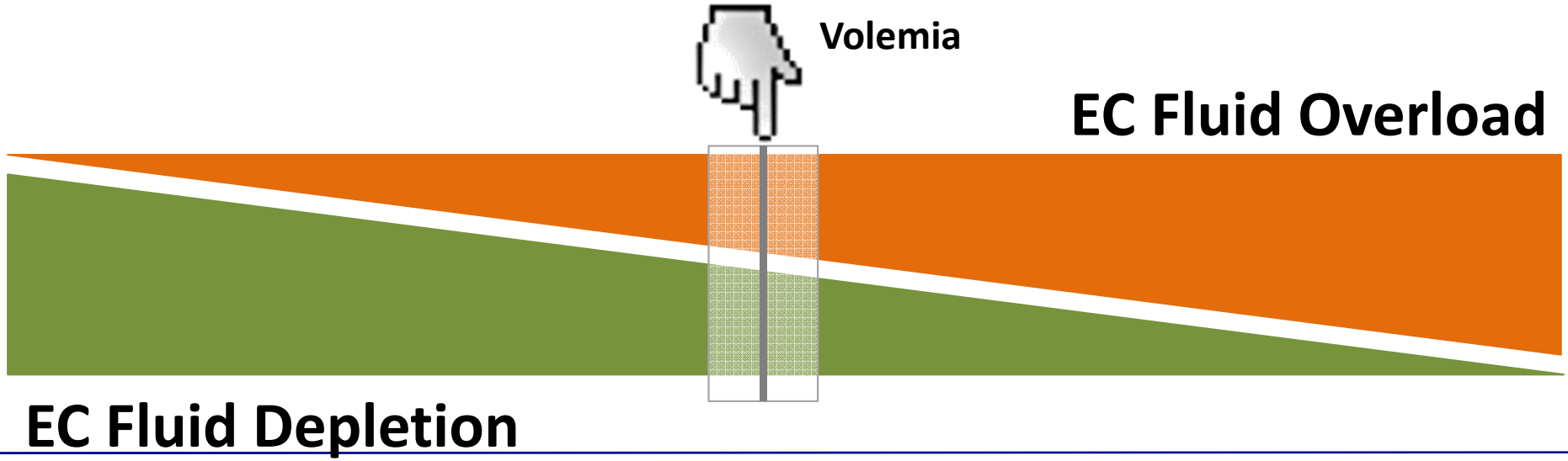
Mean Arterial Pressure



Na & Fluid Mass Balance in Intermittent HD

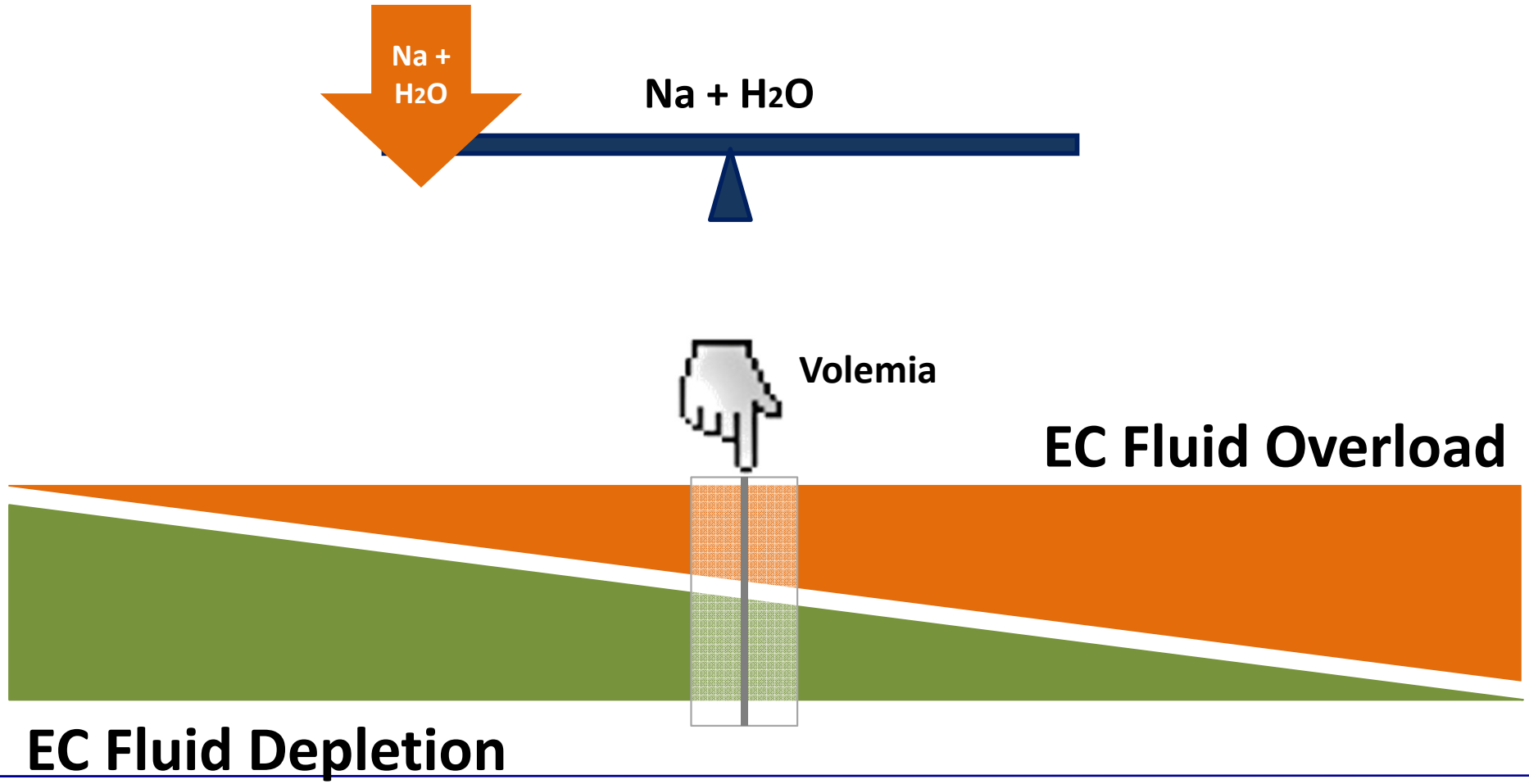
A Trade-Off Situation





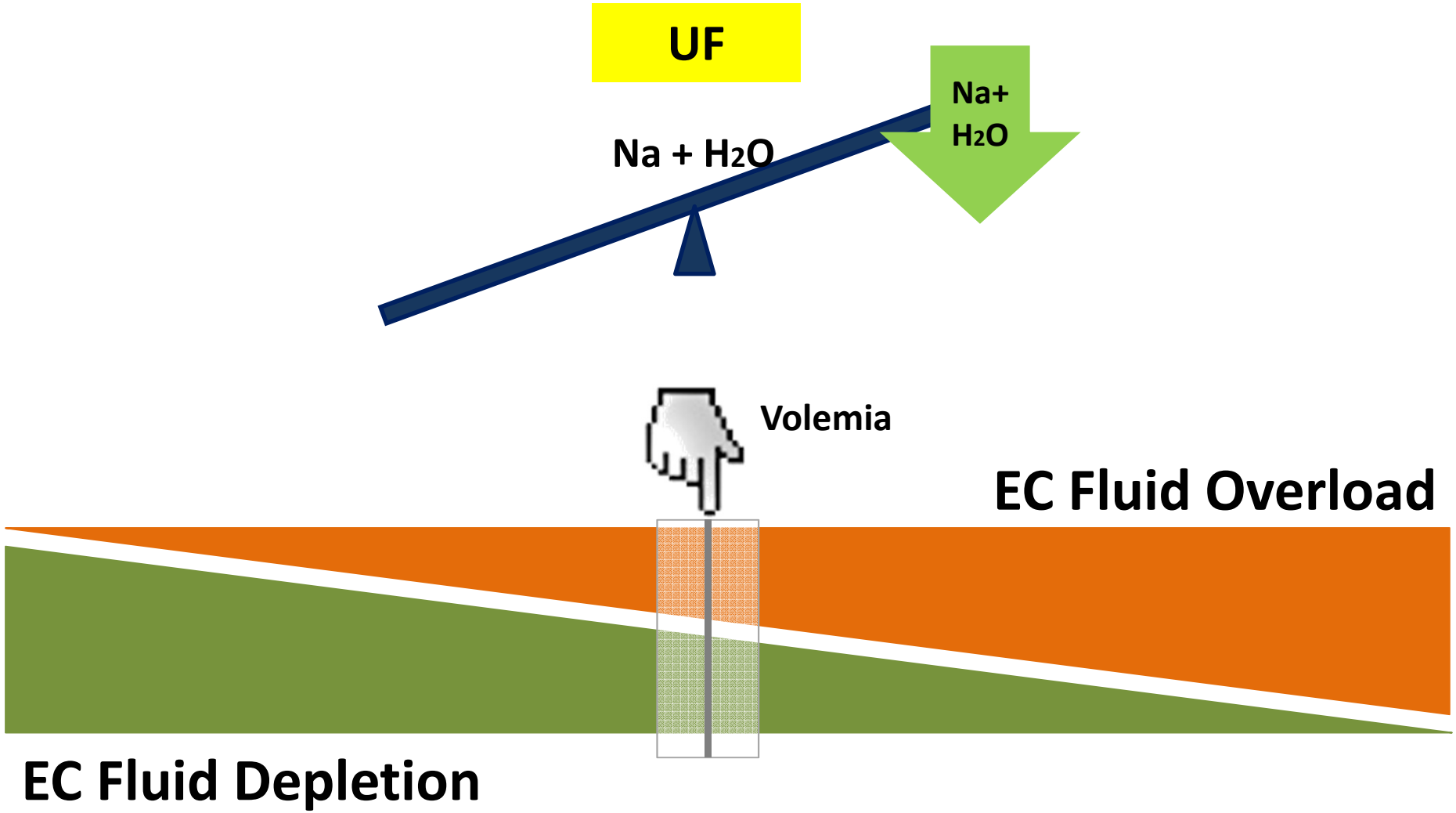
Na & Fluid Mass Balance in Intermittent HD

Interdialytic Period = Na and Fluid Gain



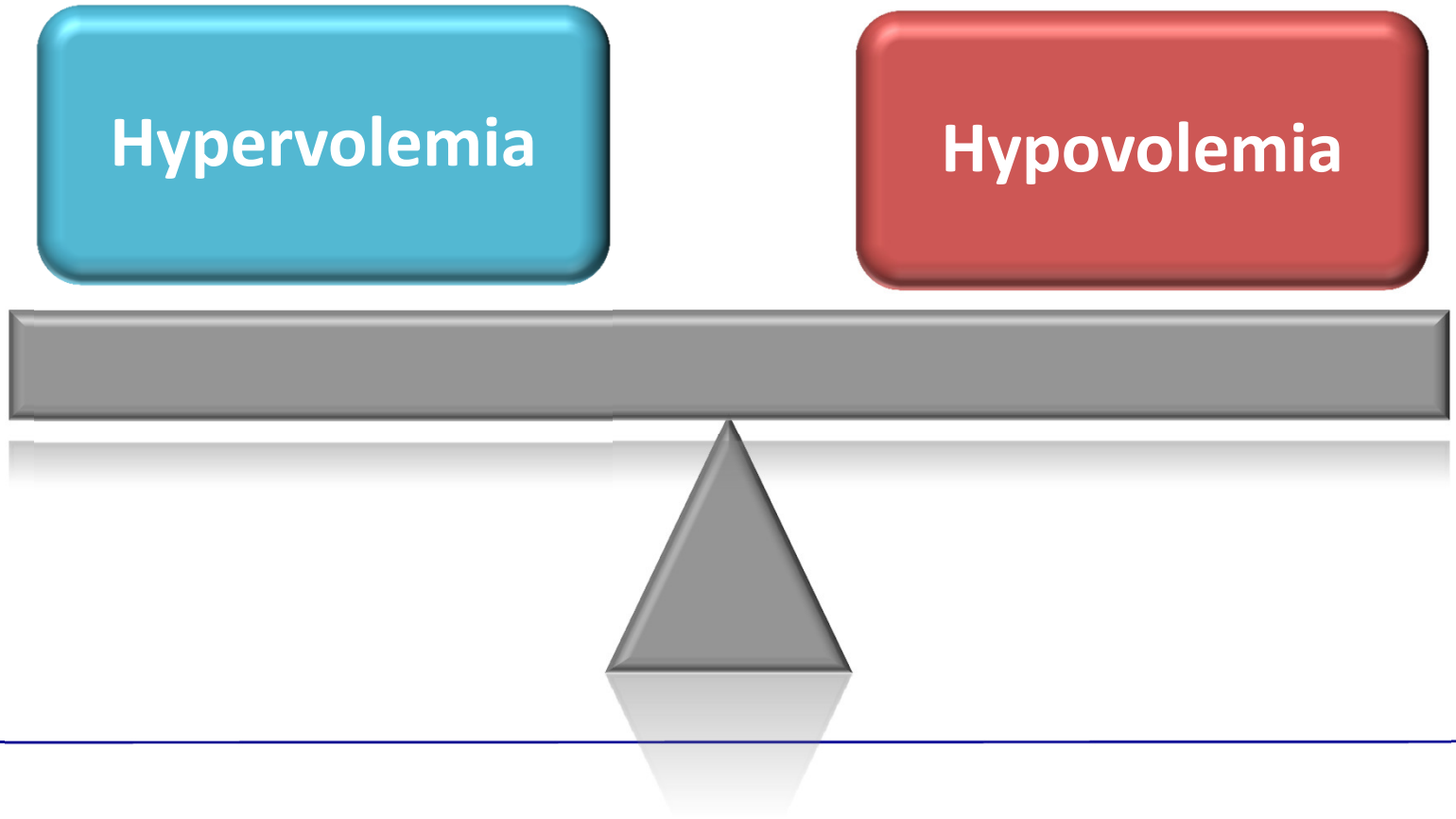
Na & Fluid Mass Balance in Intermittent HD

Intradialytic Period = Na and Fluid Depletion



Volemia Changes
Unphysiologic State

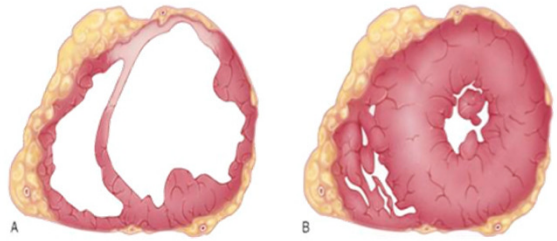
Interdialytic = **Intradialytic**



EC Fluid Overload : Consequences

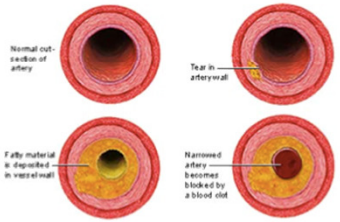
- Hypertension
- Cardiac remodeling :
  - Dilation – Hypertrophy
- Arterial vascular remodeling :
  - Stiffness – Endothelial dysfunction
- Lung edema :
  - Lung hypertension - Fibrosis
- Additional side effects :
  - Inflammation – Anemia
  - Malnutrition…

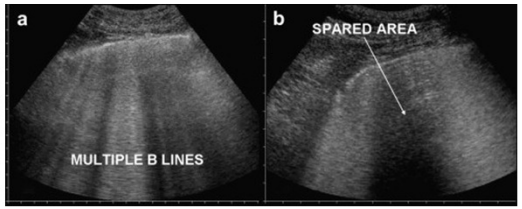
Hypertension
Na Mass Excess…

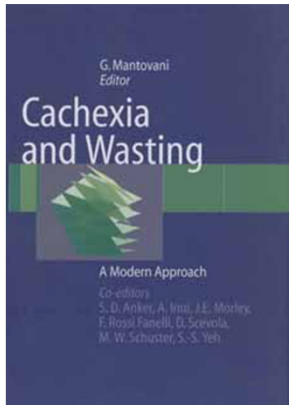


Dilated cardiomyopathy

Hypertrophy cardiomyopathy

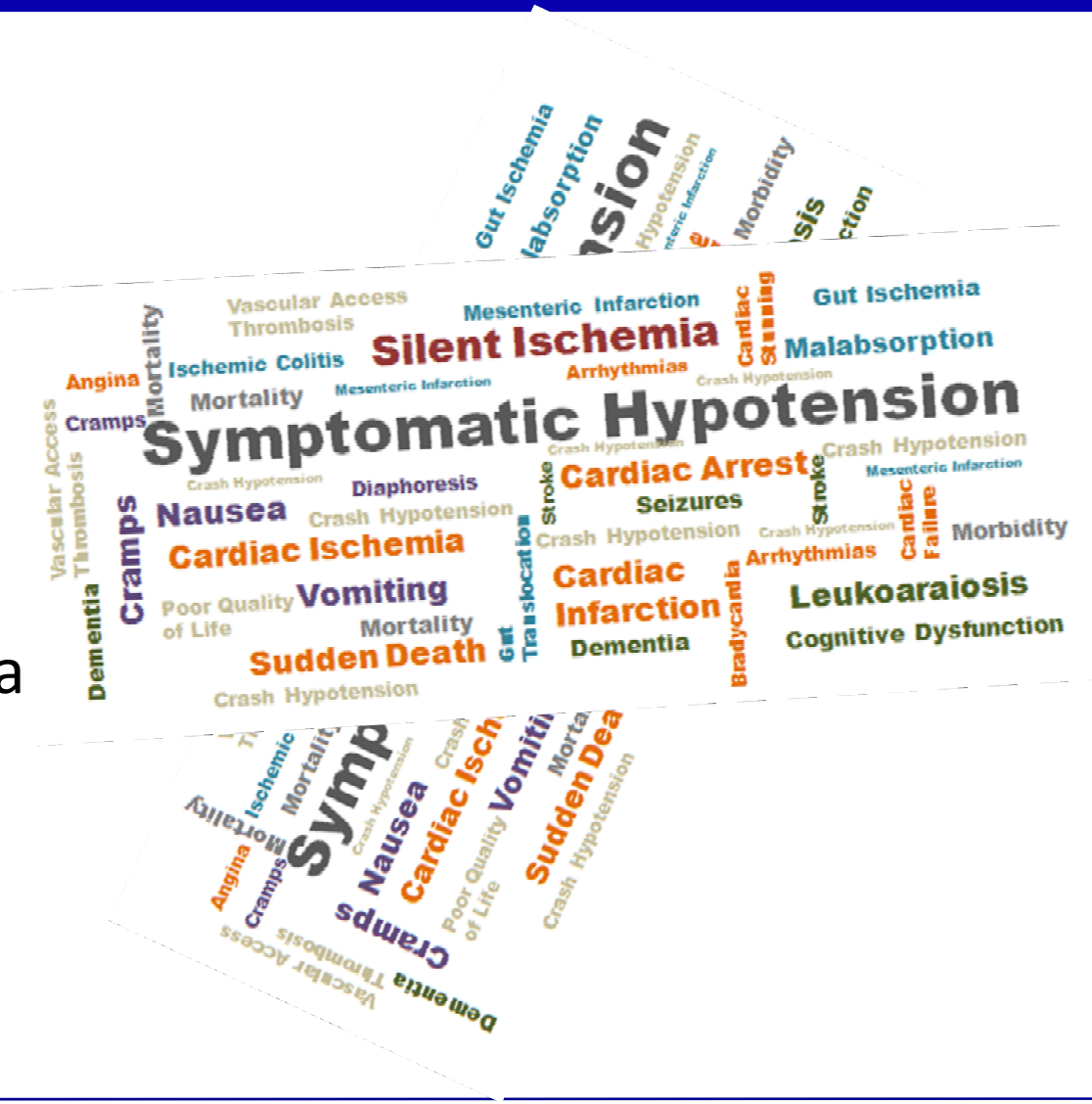






EC Fluid Depletion : Consequences

- Chronic hypovolemia
  - Silent ischemia …
- Symptomatic hypotension
  - nausea, vomiting, diaphoresis, cramps
- Crash hypotension
- Angina, Bradycardia, Arrhythmia
- Seizures, Stroke
- Vascular thrombosis
- Cardiac arrest …

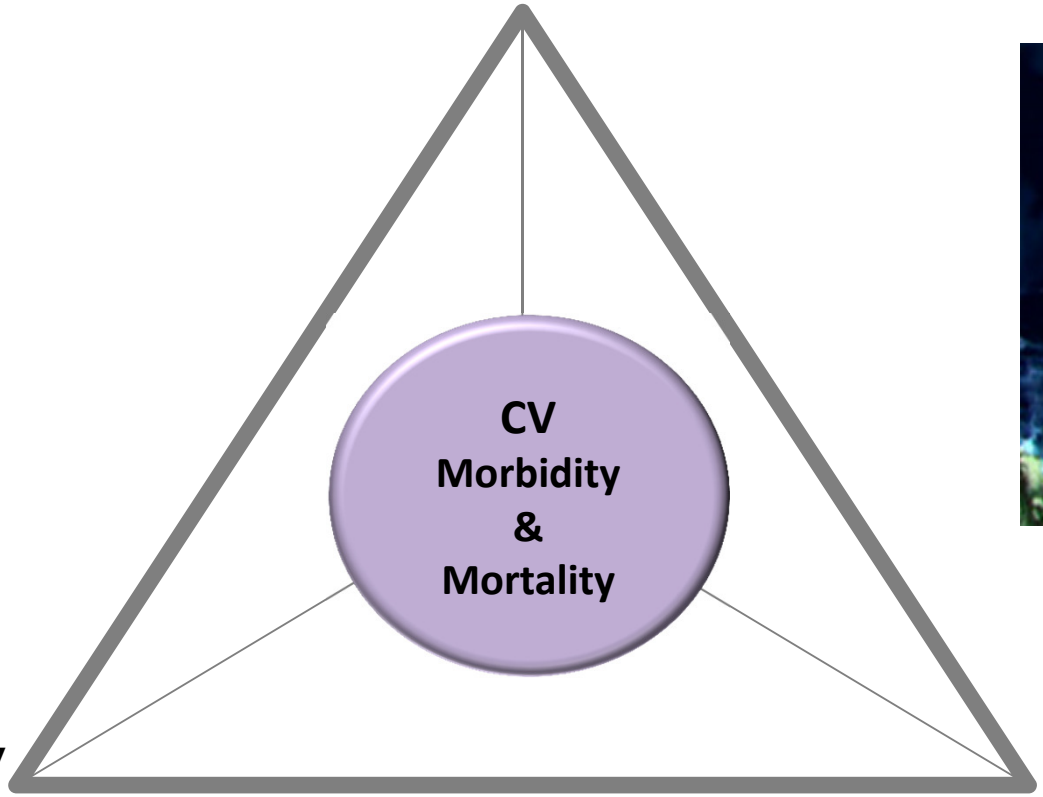


Management of Na Mass Balance & Fluid Volume

'Bermuda Triangle' for HD Patient

Na & Fluid Mass Balance

Extracellular Volume (volemia)



Osmolality Change

Blood Pressure

Outlook of the Presentation

1. Sodium & fluid volume homeostasis in CKD5 HD patient
   - Basics of physiology – Challenges for nephrologist & care giver
2. **Intradialytic hypotension:**
   - **Definition – Frequency – Causes – Consequences**
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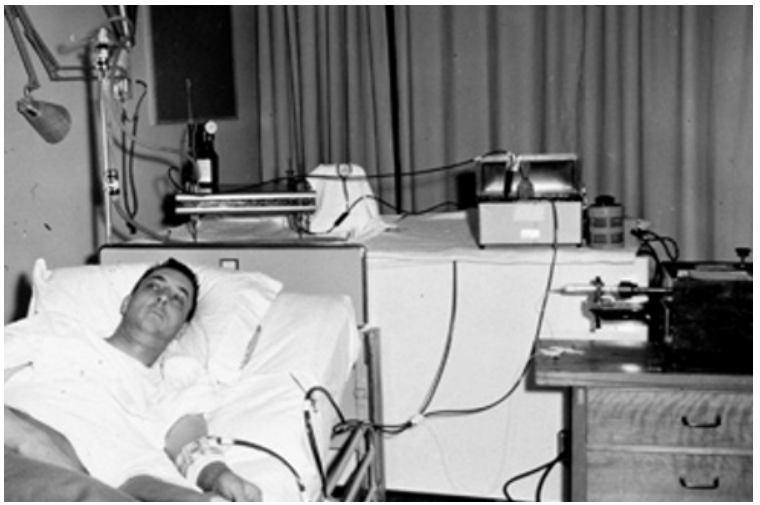
Intra Dialytic Hypotension (IDH)
Definition of Symptomatic Hypotension

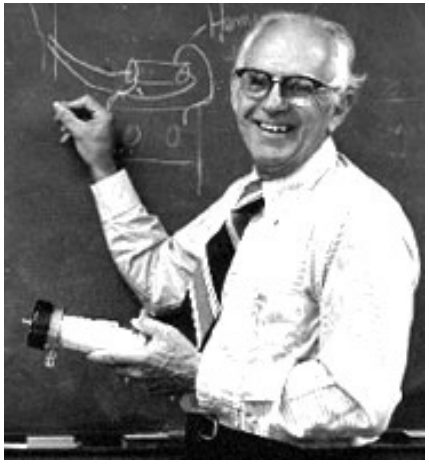
- Various definitions in scientific studies have created lot of confusion in research studies.
- European Best Practice Guidelines (**EBPG**) define intradialytic hypotension (IDH) as **both** a **fall in blood pressure** and the **occurrence of symptoms needing an intervention**.
- A **fall in SBP** by **at least 20mmHg** or a decrease in mean arterial pressure by at least 10mmHg is required to qualify for the diagnosis of hypotension.

Kooman J et al. EBPG guideline on haemodynamic instability. *Nephrol Dial Transplant* 2007; 22 (Suppl 2):ii22–ii44.

Intra Dialytic Hypotension

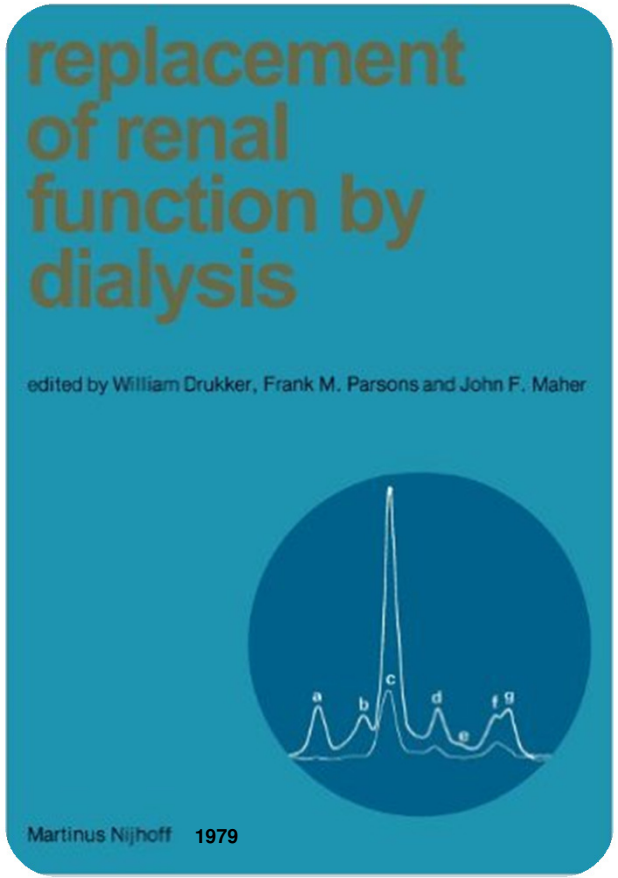
A Quite Common Phenomenon in the Pioneering Phase of Dialysis





Scribner BH, Buri R, Caner JEZ, Hegstrom R, Burnell JM. The treatment of chronic uremia by means of intermittent hemodialysis: a preliminary report. Trans Am Soc Artif Intern Organs. 1960;6:114-122.

IntraDialytic Hypotension Reduced Over Time



Hypotension

Episodes of hypotension occur in 20% to 30% of all hemodialyses (5, 6), and relate to various factors affecting cardiac output and systemic vascular resistance (7, 8). Cardiac output depends on myocardial contractility and filling volume, which in turn relates to vascular volume and heart rate, the

increase

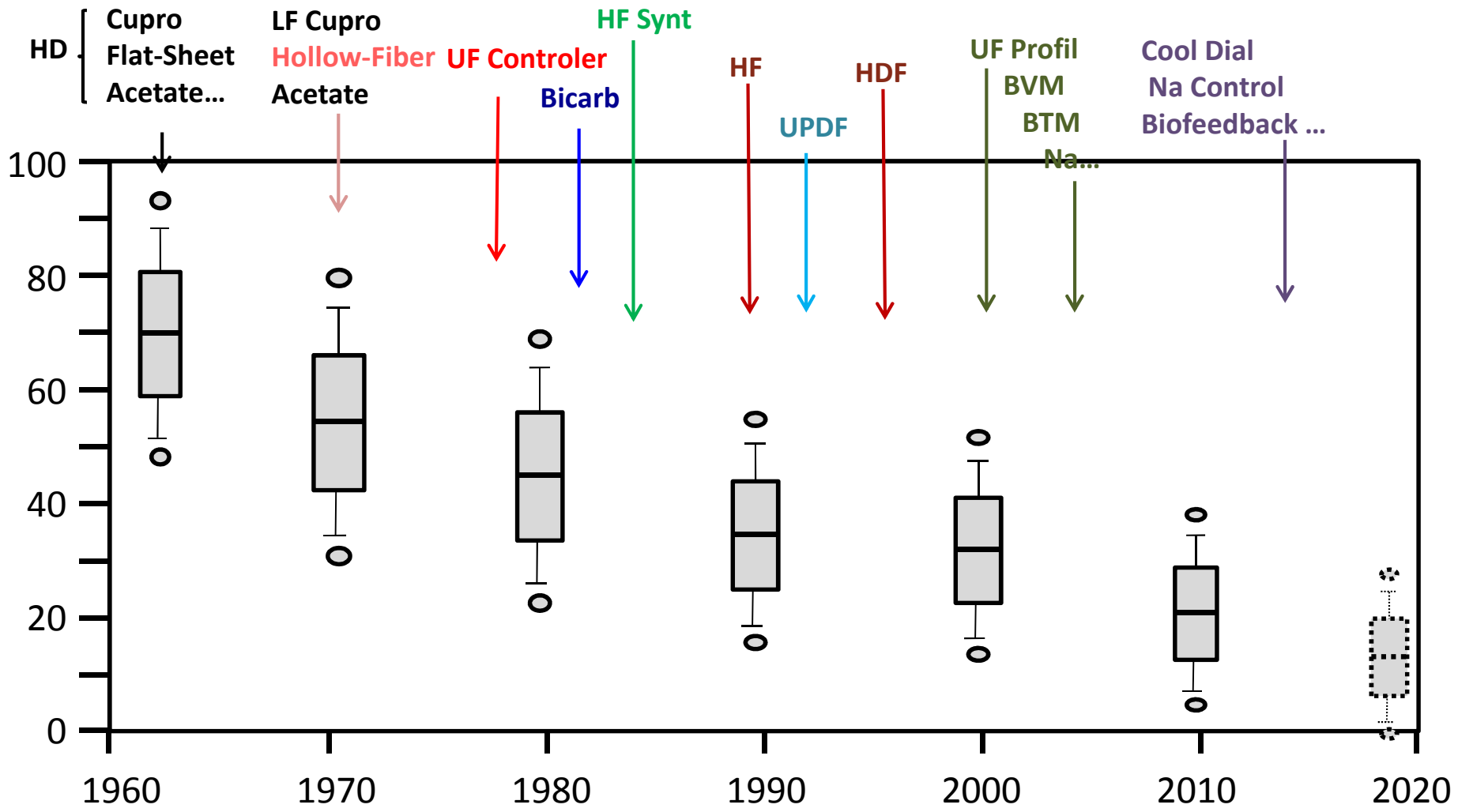
temic vas

The role of acetate and hypoxemia

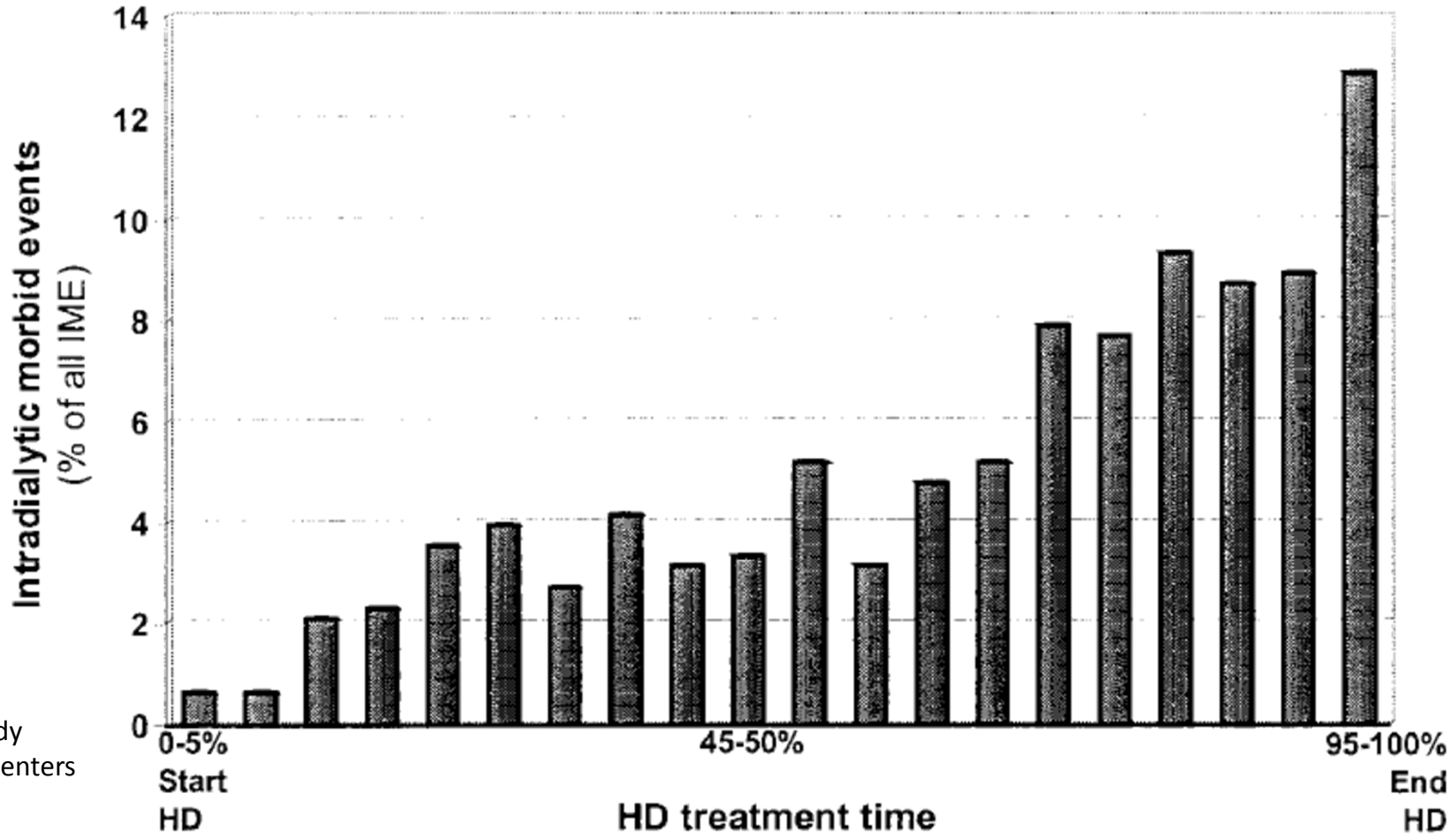
With development of automated single-pass dialysis equipment in the 1960s, acetate became the standard anion in dialysate, replacing bicarbonate because of the need to prevent precipitation of calcium and magnesium (18). Acetate is readily metabolized in the body, resulting in the regeneration of bicarbonate from carbon dioxide (19).

More recently, with larger surface area dialyzers and more rapid dialysis, transport of acetate into blood can occur at a rate exceeding the capacity of the body to metabolize it, and this is associated with hypotension (20, 21). Acetate ion is a vasodilator (22), and during dialysis the drop in systemic

Incidence of Intradialytic Hypotension



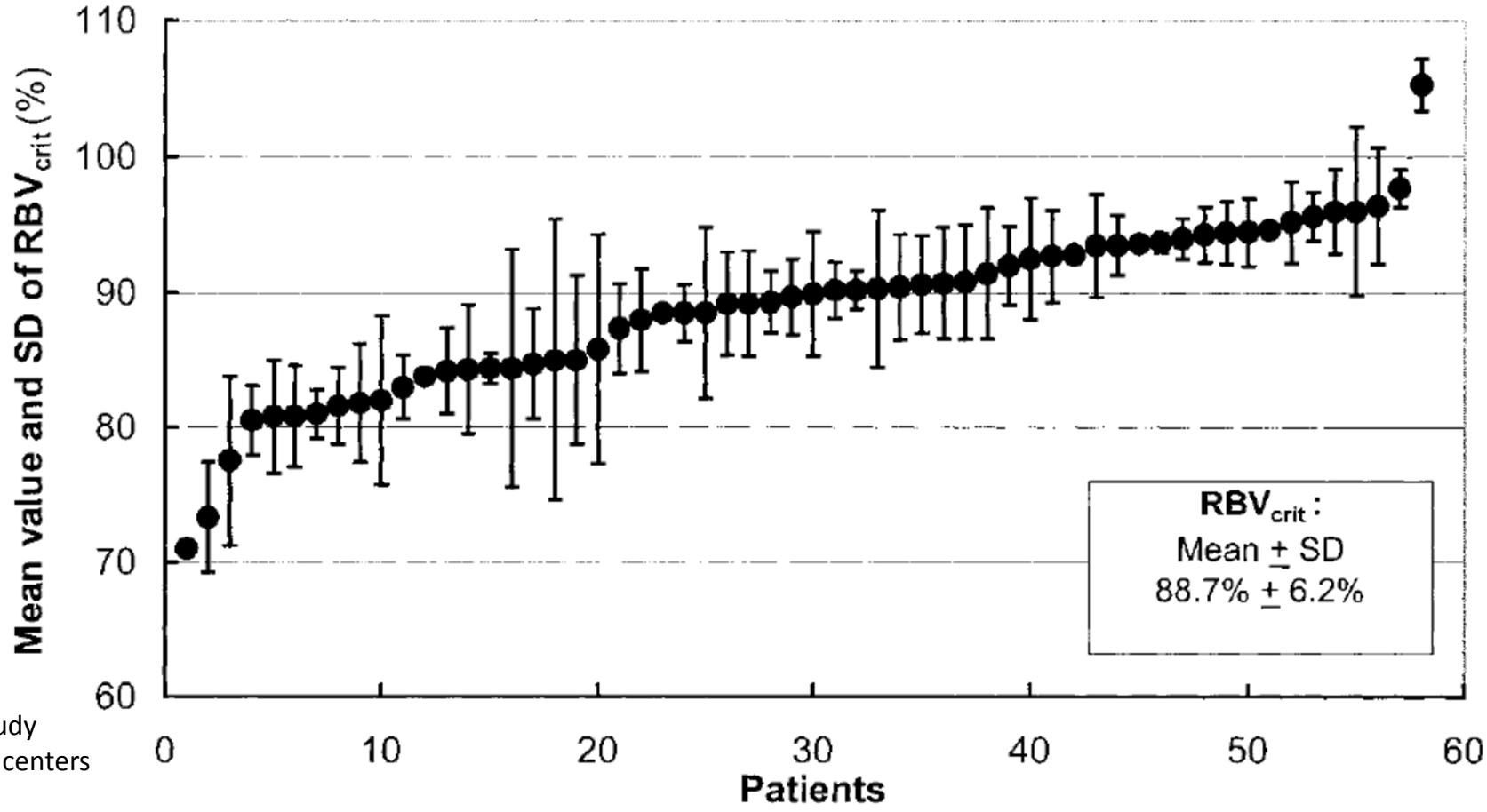
Distribution of IDH Over HD Session



Prospective multicenter study
60 IDH prone pts 9 dialysis centers
Monitored 21 HD sessions
No intervention
RBV changes monitored

Barth C et al, *Nephrol Dial Transplant* 2003; 18: 1353-1360

Individual Relative Blood Volume Changes
Relative Critical Volume is Individual



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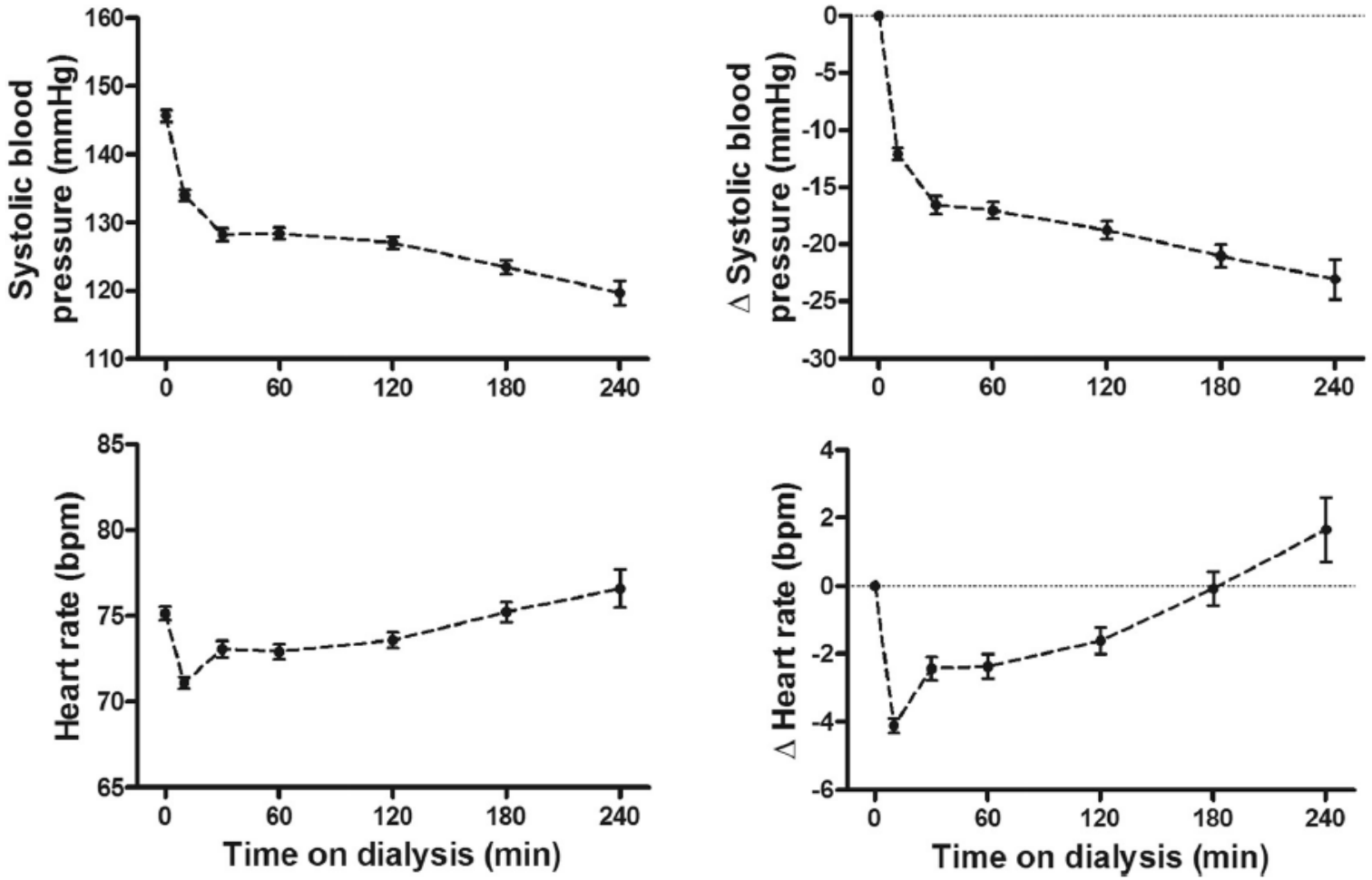
Hemodynamic Changes Occurring During HD Sessions



University Medical Center Groningen
Incenter Dialysis Unit – 3 mo prospective study
Hemodynamic data - EBPG definition
124 adult HD pats – 3818 HD sessions

Kuipers et al, *BMC Nephrology* 2016;17:21

Prevalence of Intradialytic Hypotension, Clinical Symptoms and Nursing Interventions

	Nr of dialysis sessions (%)
Blood pressure drop	
Decrease in SBP ≥20 mmHg	2434 (63.8)
Clinical events	
Any clinical event	817 (21.4)
Nursing interventions	
Any [illegible]	[illegible]
Bl[illegible]	610 (16.0)
BP [illegible]ination with a nursing intervention	
Decrease in SBP ≥20 mmHg	285 (7.5)

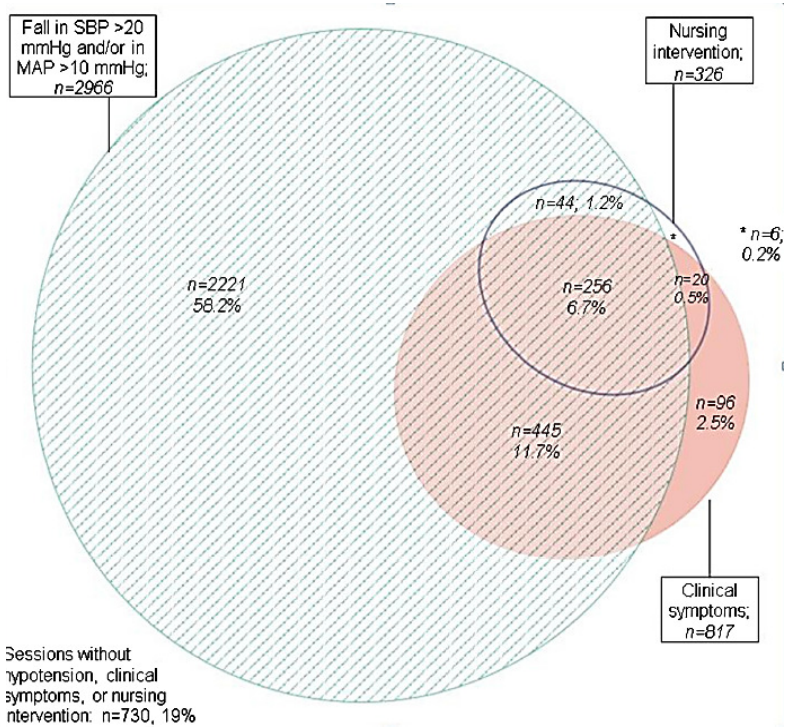
Values are given as number (percentage). The total number of patients with clinical events and nursing interventions is lower than the separate items since some patients had more than one clinical event and/or intervention
Abbreviations: BP blood pressure, SBP systolic blood pressure. MAP mean arterial blood pressure

Prevalence(%)

Decrease in SBP ≥20 mmHg or MAP ≥10 mmHg : 77.7

Clinical symptoms : 21.4

Nursing interventions : 8.5



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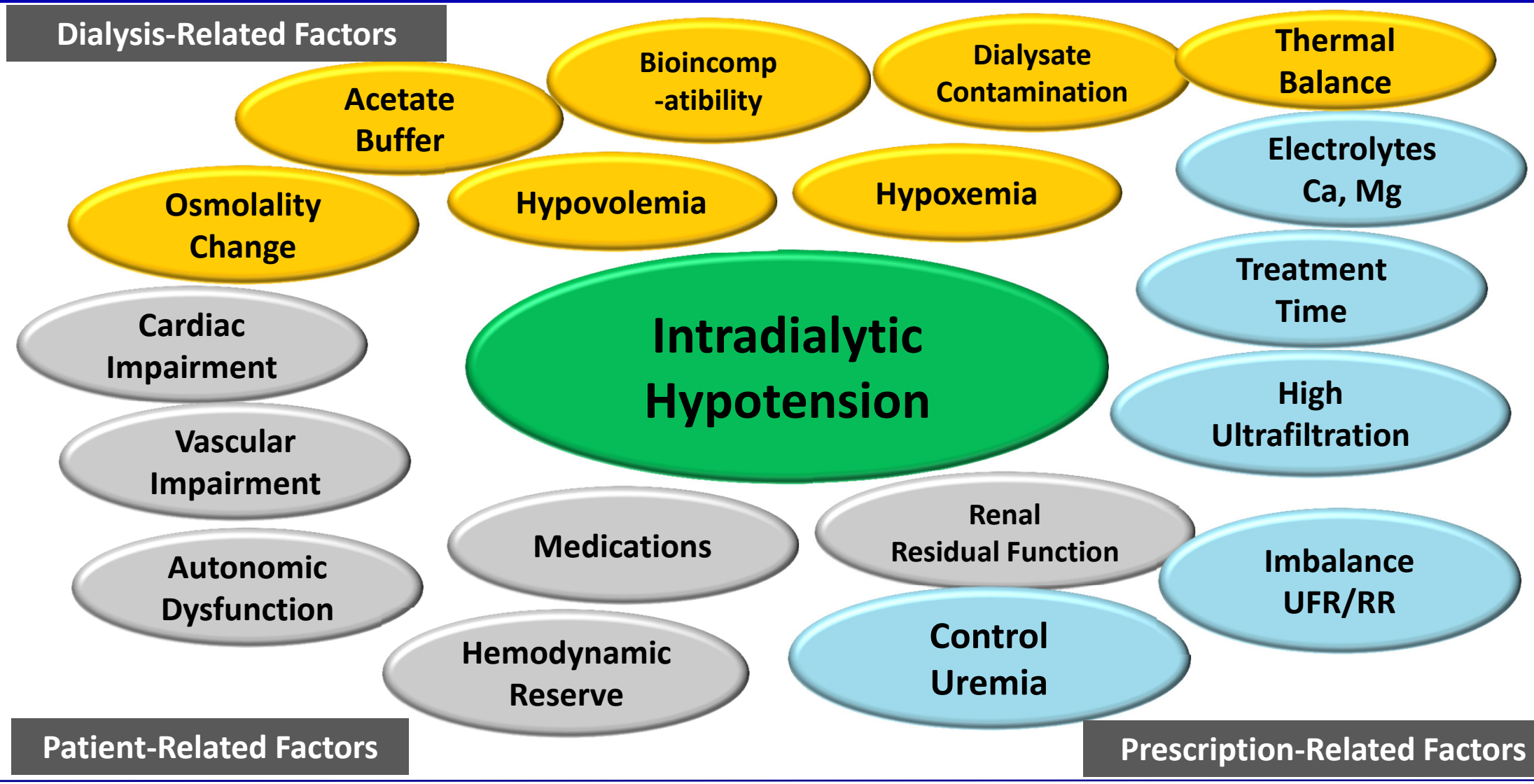
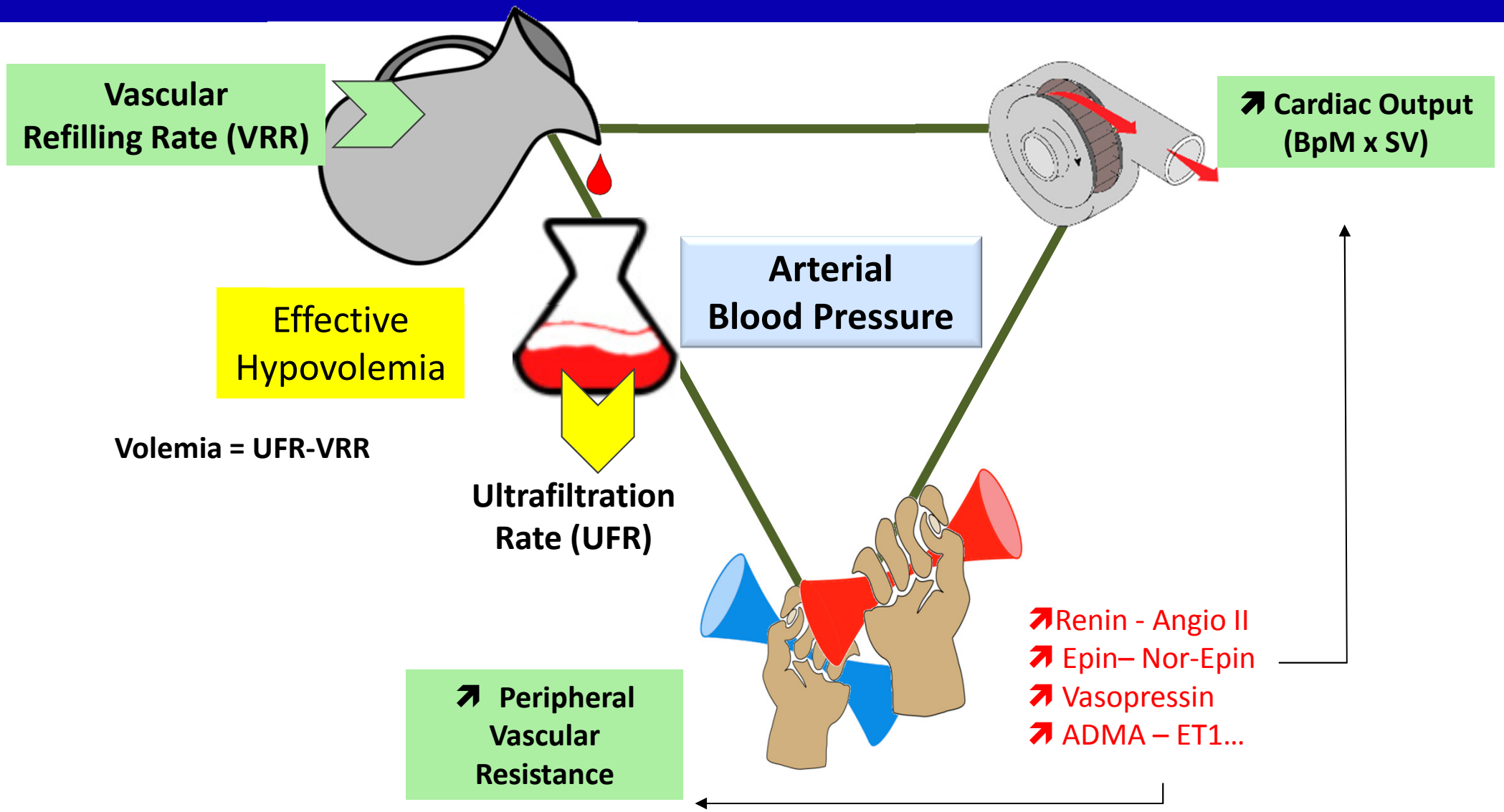
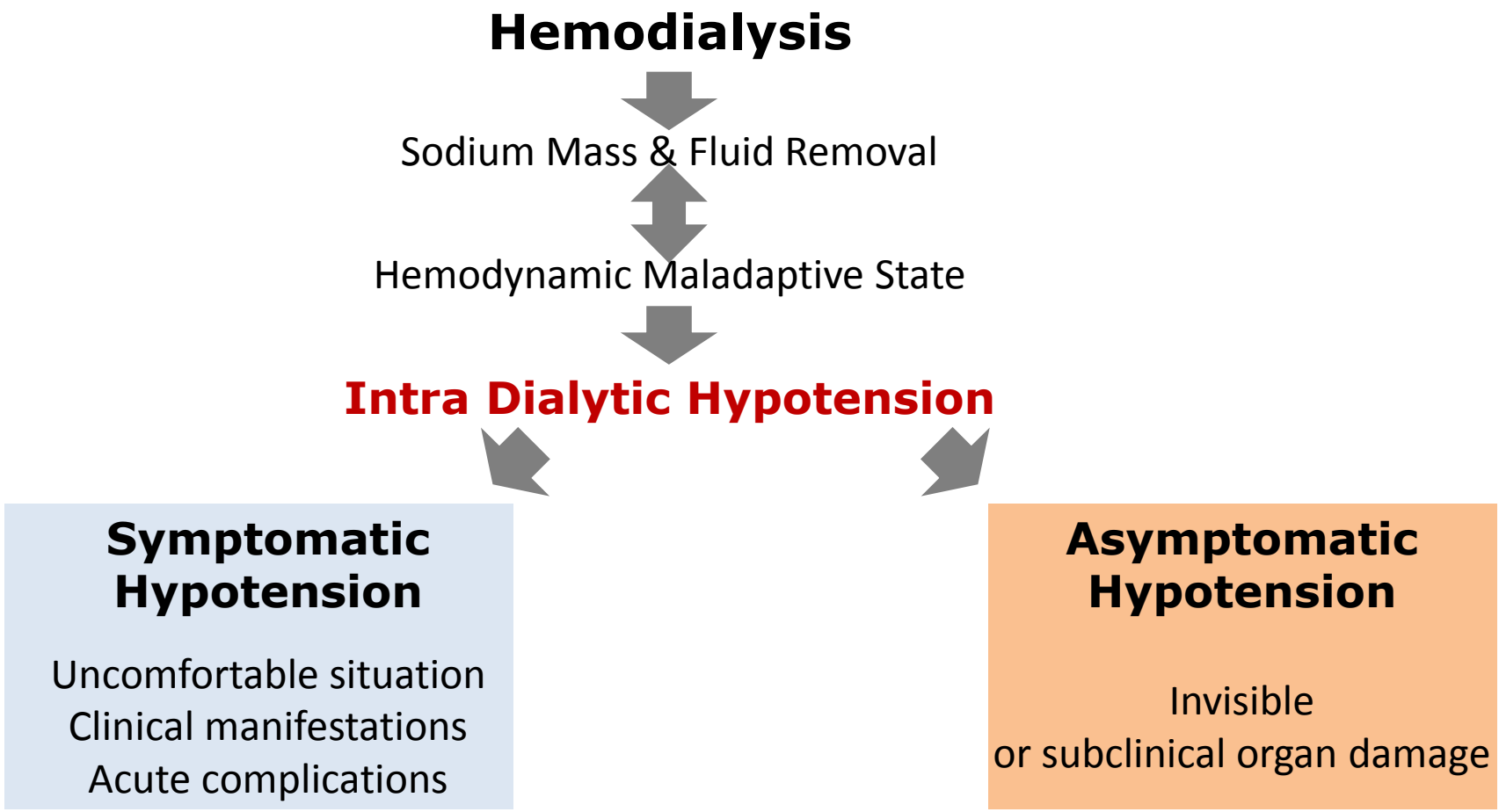
Causes of Intradialytic Hypotension



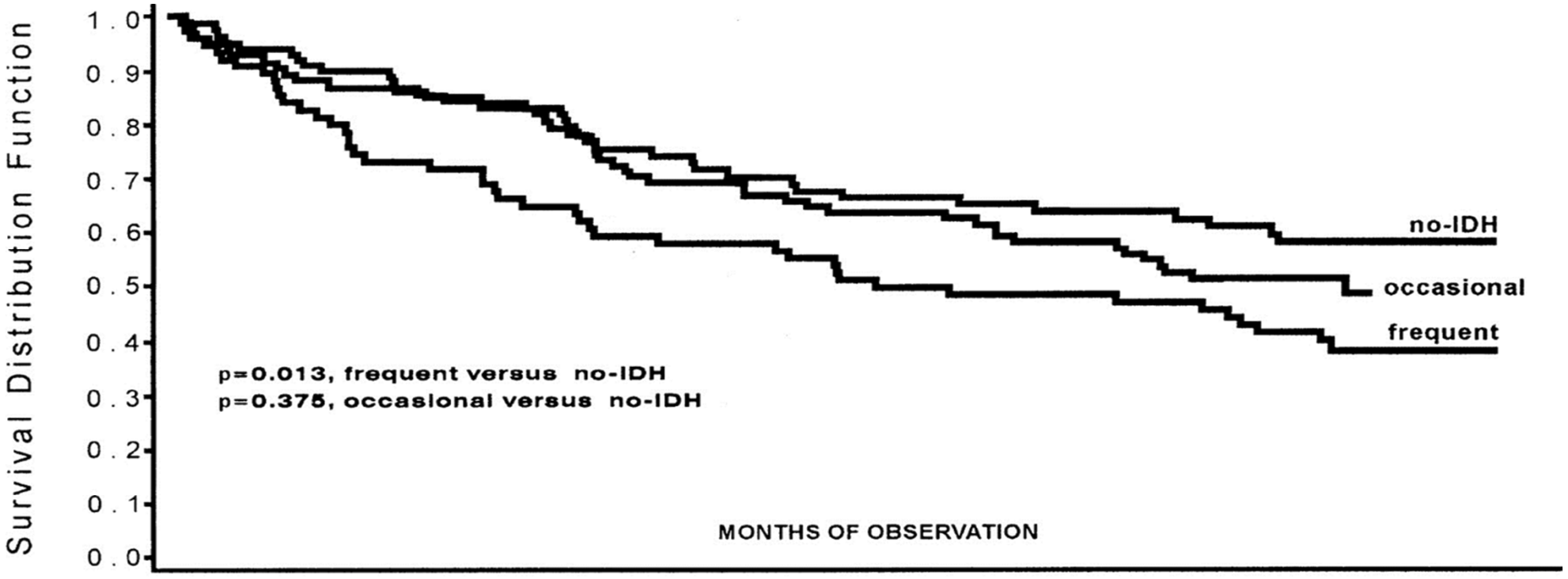
Factors Preserving Hemodynamic Stability during HD with Ultrafiltration



Intra Dialytic Hypotension
Maladaptive State



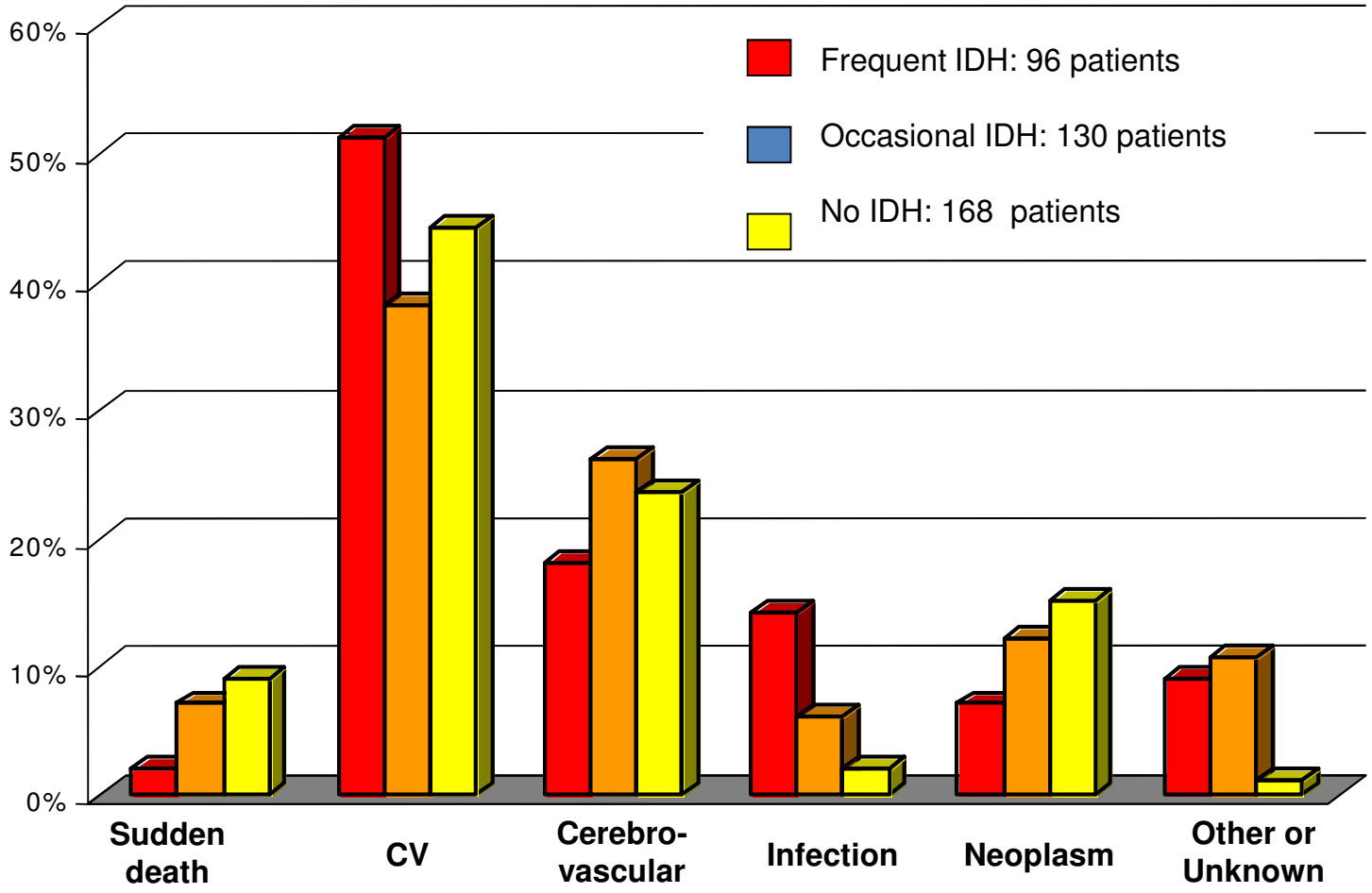
Survival Curves of Patients With Frequent, Occasional or No IntraDialytic Hypotension



	0	5	10	15	20	25	30	35
no-IDH	85	72	68	55	51	48	45	42
occasional	101	30	81	65	58	51	45	19
frequent	77	56	47	42	36	35	32	20

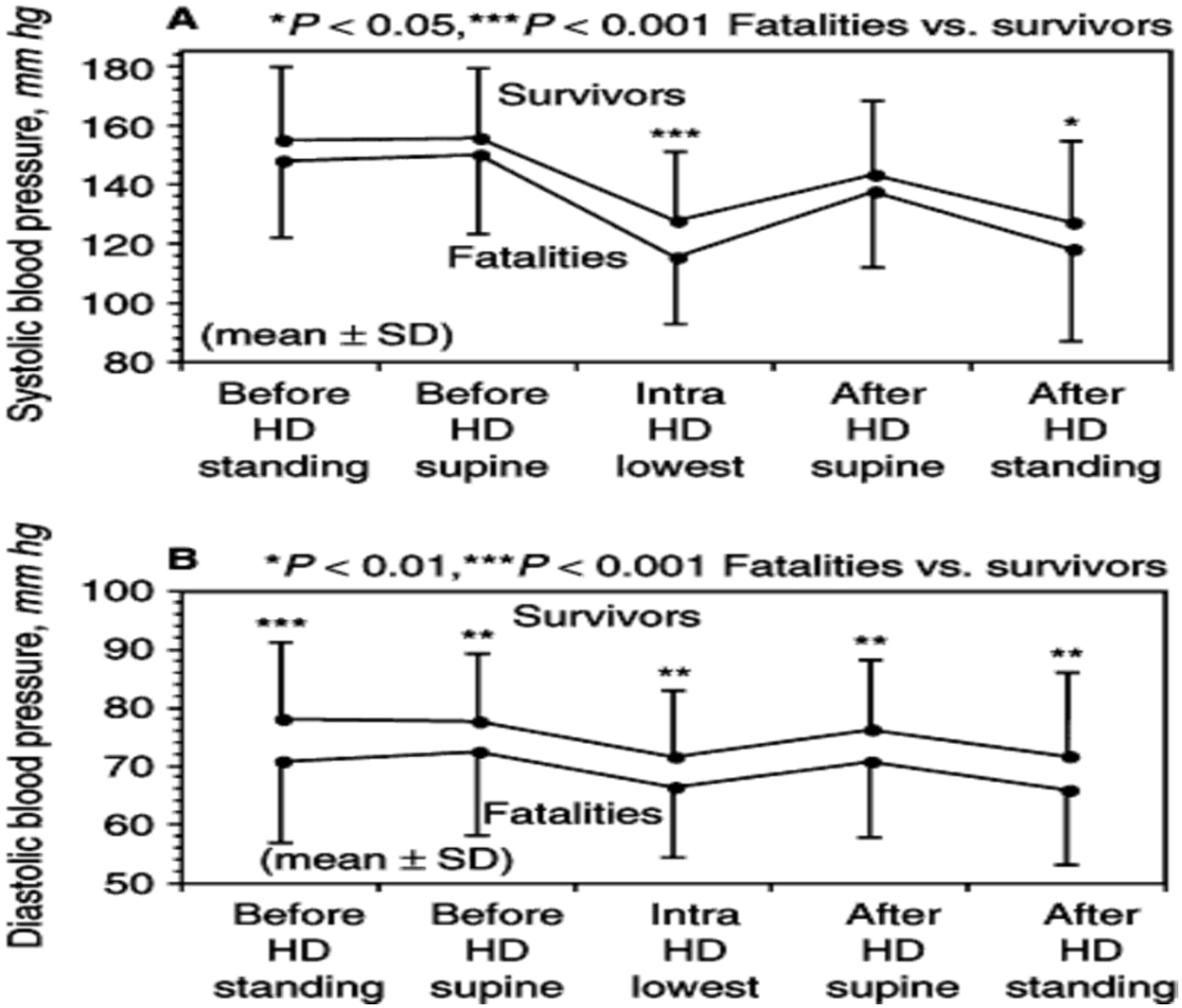
Tisler A et al, *Nephrol Dial Transplant* 2003; 18:2601

Causes of Death in Patients With Frequent, Occasional and No IDH



Tisler A et al, *Nephrol Dial Transplant* 2003; 18:2601

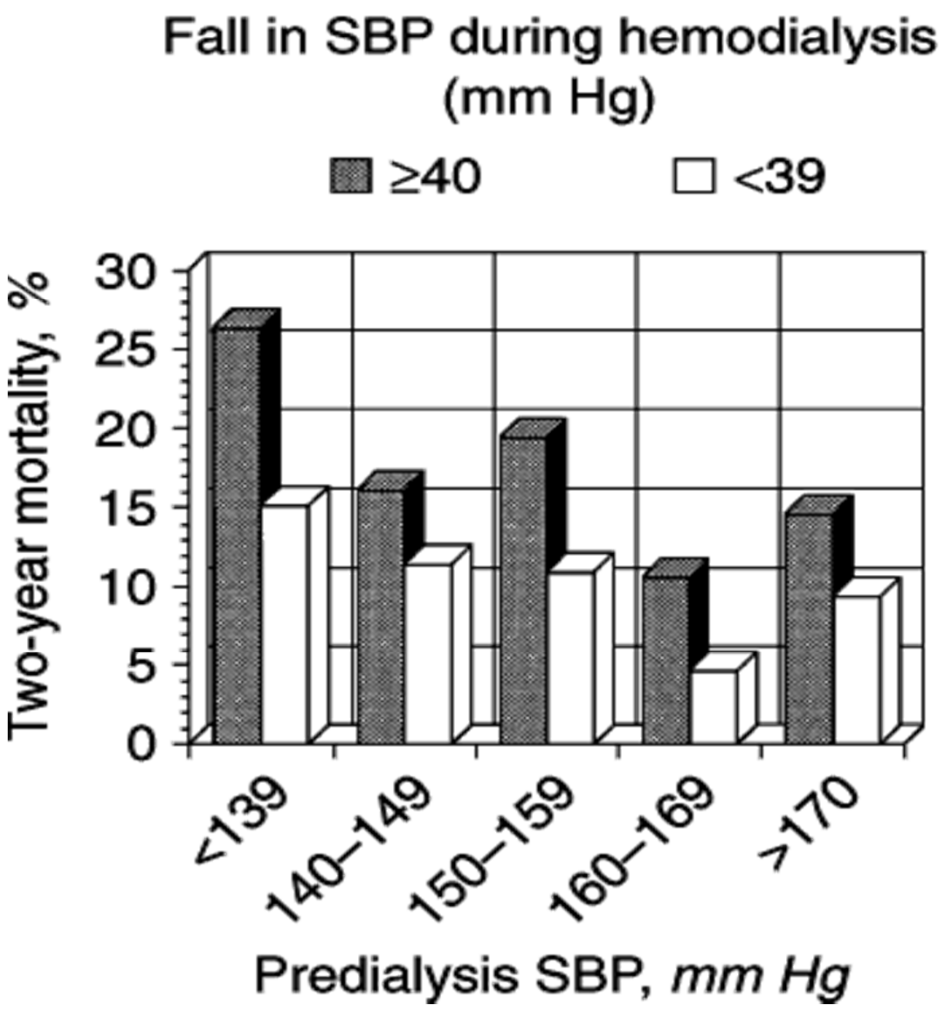
Impact of Intradialytic Hypotension on Mortality

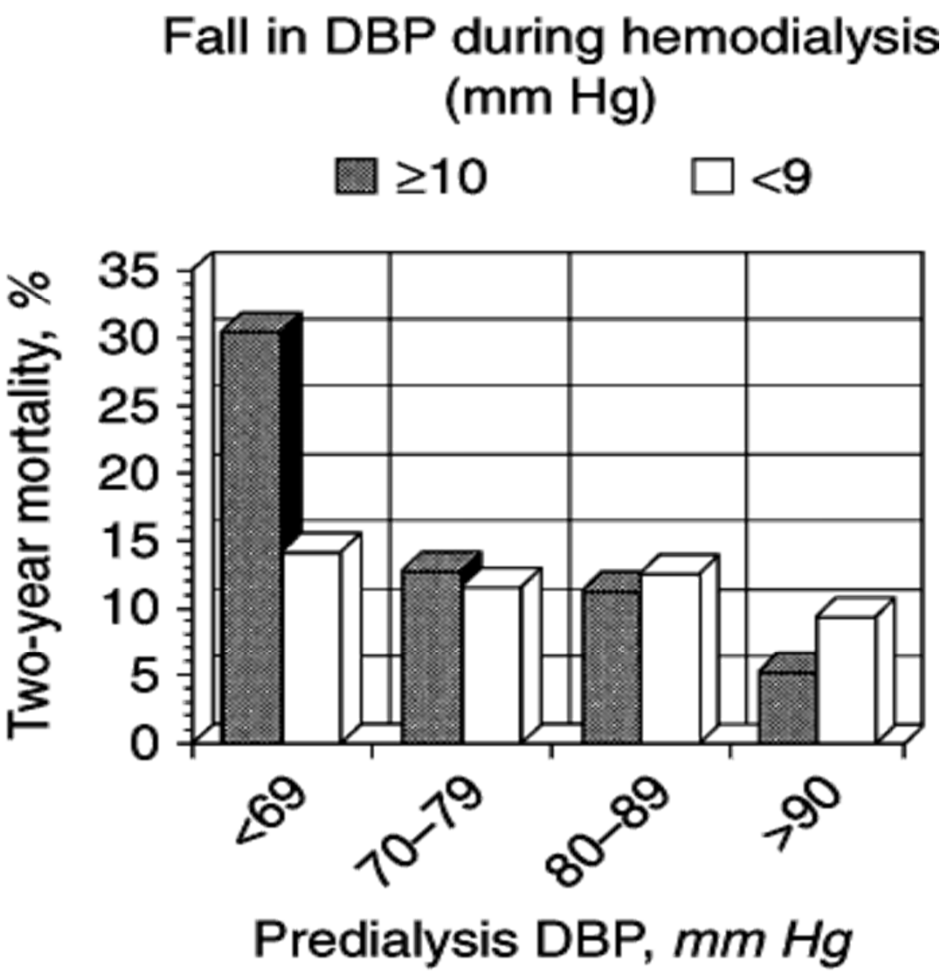


Japanese study
1244 HD patients
28 HD units
2 years follow-up

Shoji T et al, *Kidney Int.* 2004; 66(3):1212-20.

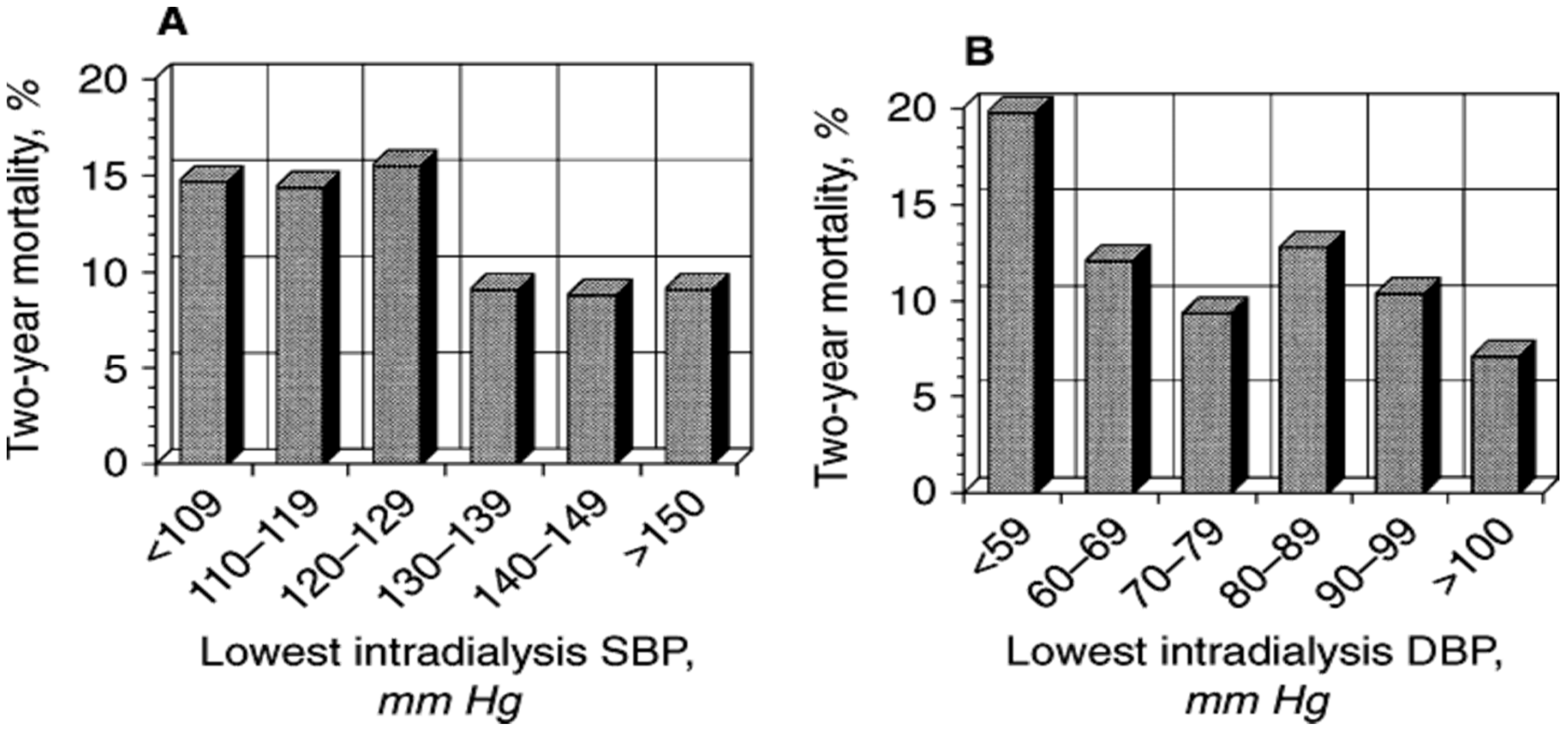
Two-Years Mortality Associated with Predialysis Blood Pressure and Fall During Hemodialysis





Shoji T et al, *Kidney Int.* 2004; 66(3):1212-20.

Two-year mortality is associated with a low intradialytic blood pressure



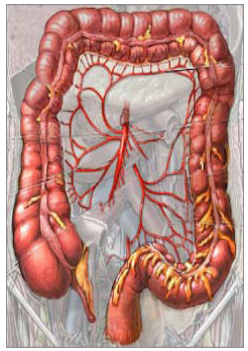
Shoji T et al, *Kidney Int.* 2004; 66(3):1212-20.

Intra Dialytic Hypotension Induces Hemodynamic Stress

Intradialytic Hypotension

Cardiac ischemia
Stunning

Gut ischemia
Endotoxin translocation



Brain ischemia
Leukoaraiosis

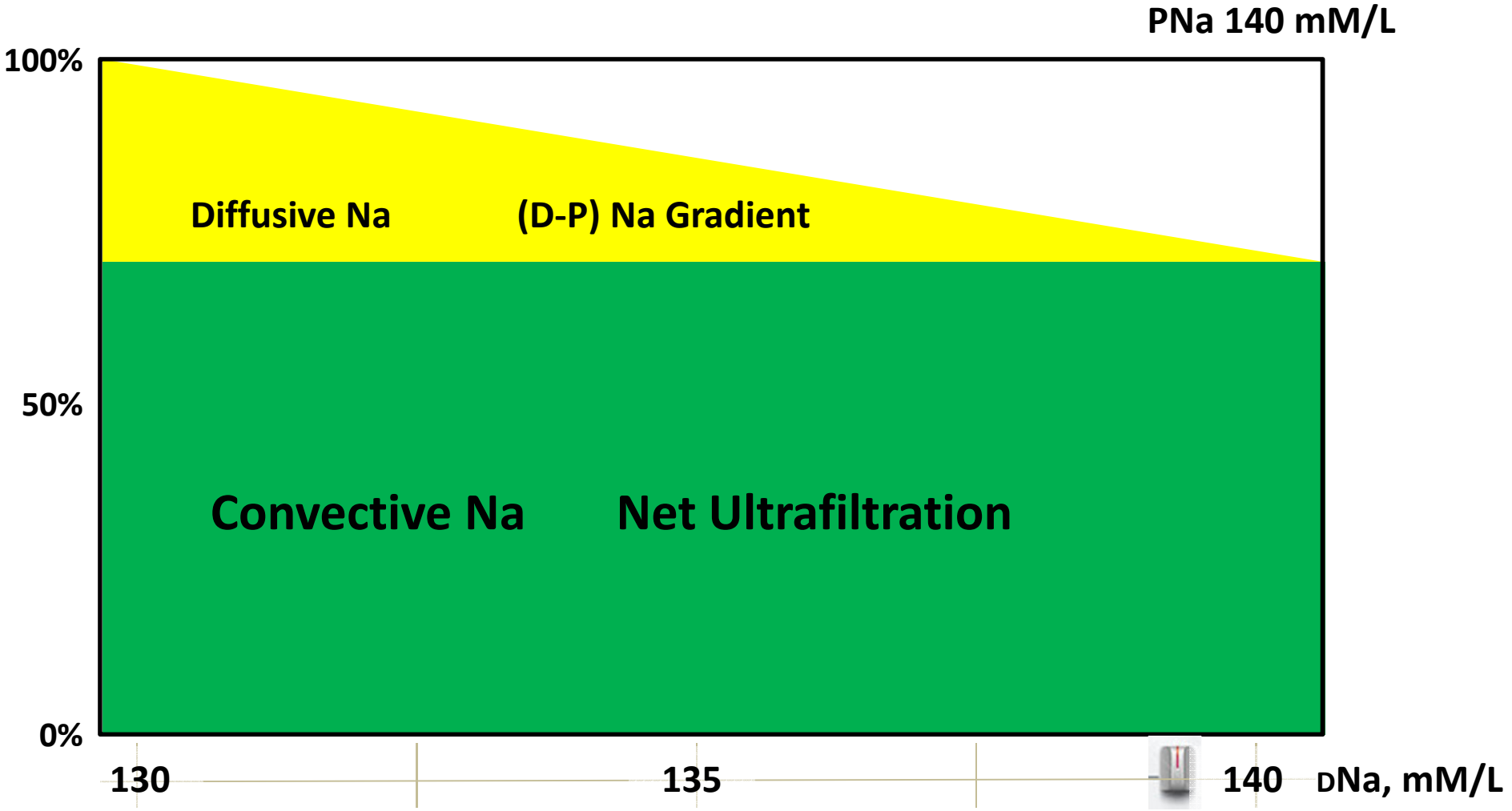
Stroke

Liver stress
Redistribution flow from portal to artery

Outlook of the Presentation

1. Sodium & fluid volume homeostasis in CKD5 HD patient
   - Basics of physiology – Challenges for nephrologist & care giver
2. Intradialytic hypotension:
   - Definition – Frequency – Causes – Consequences
3. **Sodium & fluid management in HD**
   - Diffusive/Convective Na
   - Ultrafiltration
4. Preventing intradialytic hypotension
   - Means: diet, residual kidney function, hemodialysis, time
   - Stepwise approach
5. Take home message

Relative Contribution of Diffusion and Convection to Sodium Mass Balance



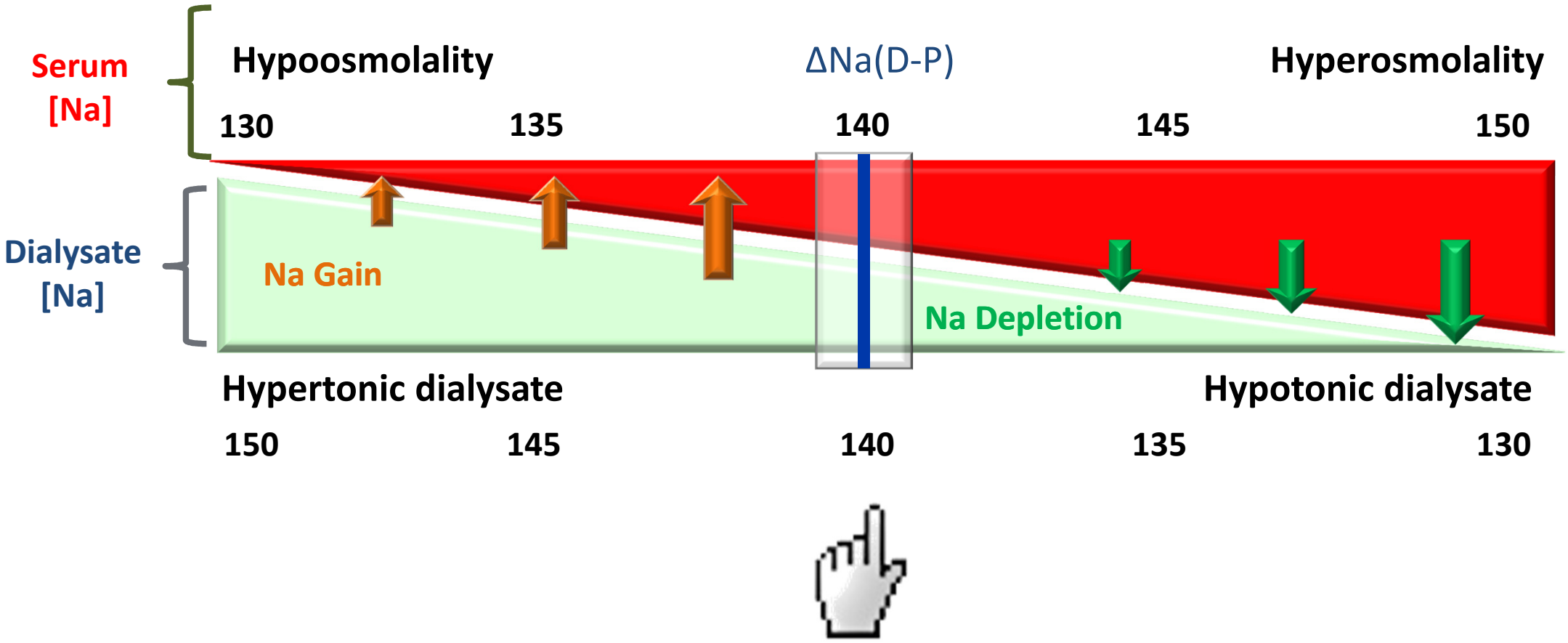
Sodium Mass Balance
Convective Removal, Ultrafiltrate

Ultrafiltrate

140 mmol/l

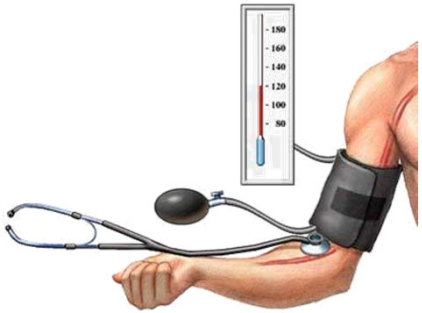
9 g NaCl per liter

Sodium Mass Balance
Diffusive Na



Extracellular Fluid Management:

Old Fashion - Clinical Tools for Probing Dry Weight



Ambulatory Blood Pressure

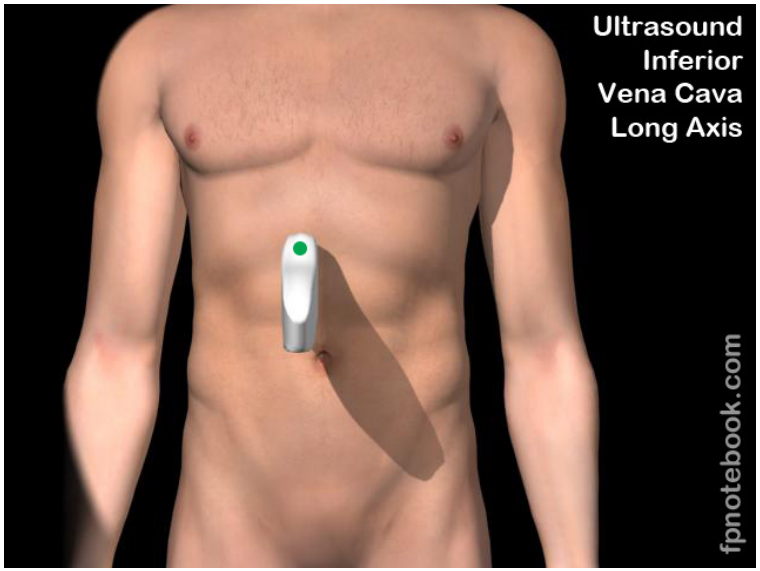
New Tools Provide More Appropriate Assessment of ABP

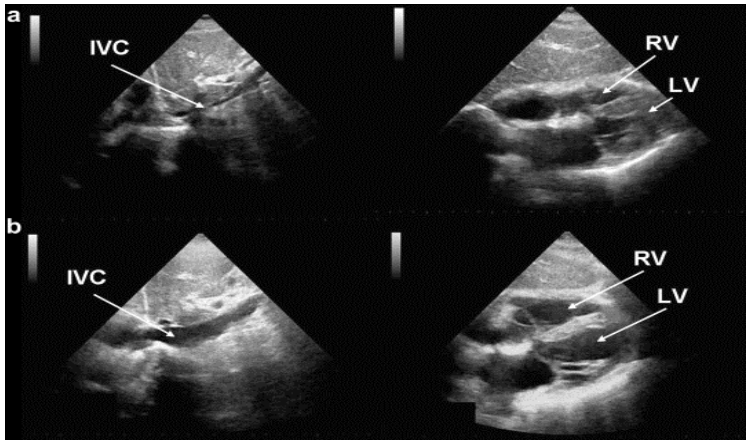
iHealth

Extracellular Fluid Management

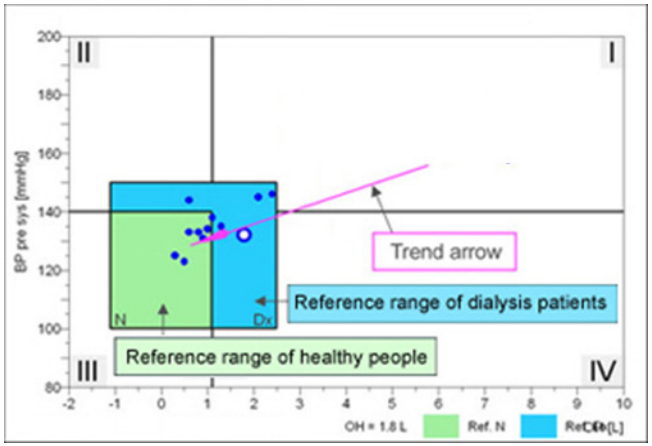
New Tools for Fluid Assessment & Management

Volemia

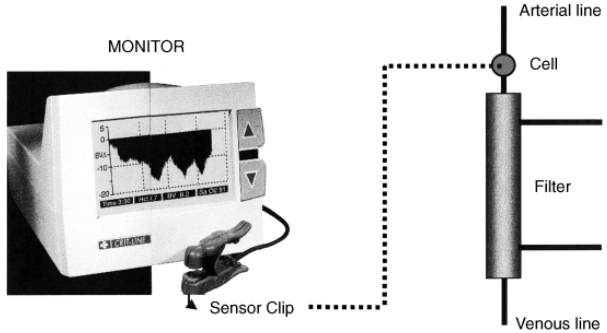




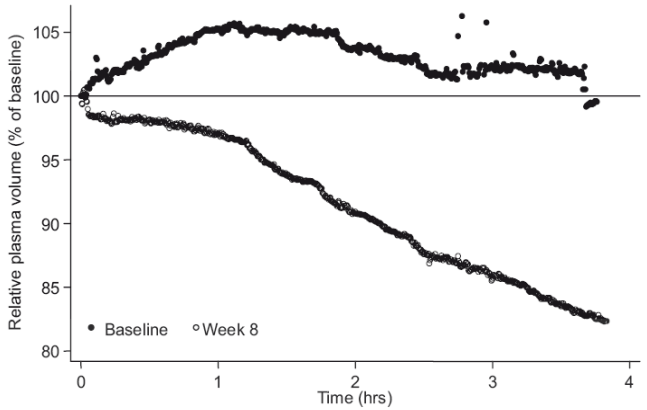
ECF/ICF



Relative Blood Volume Monitor

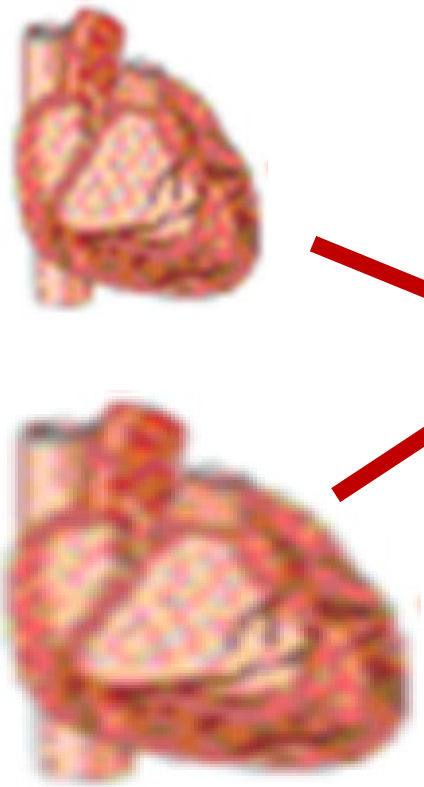


Crit-Line

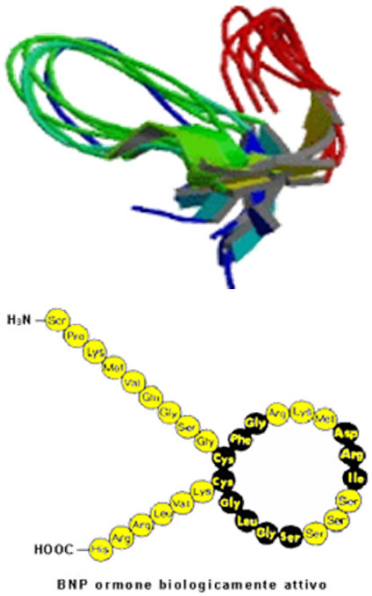


Extracellular Fluid Management
New Cardiac Biomarkers

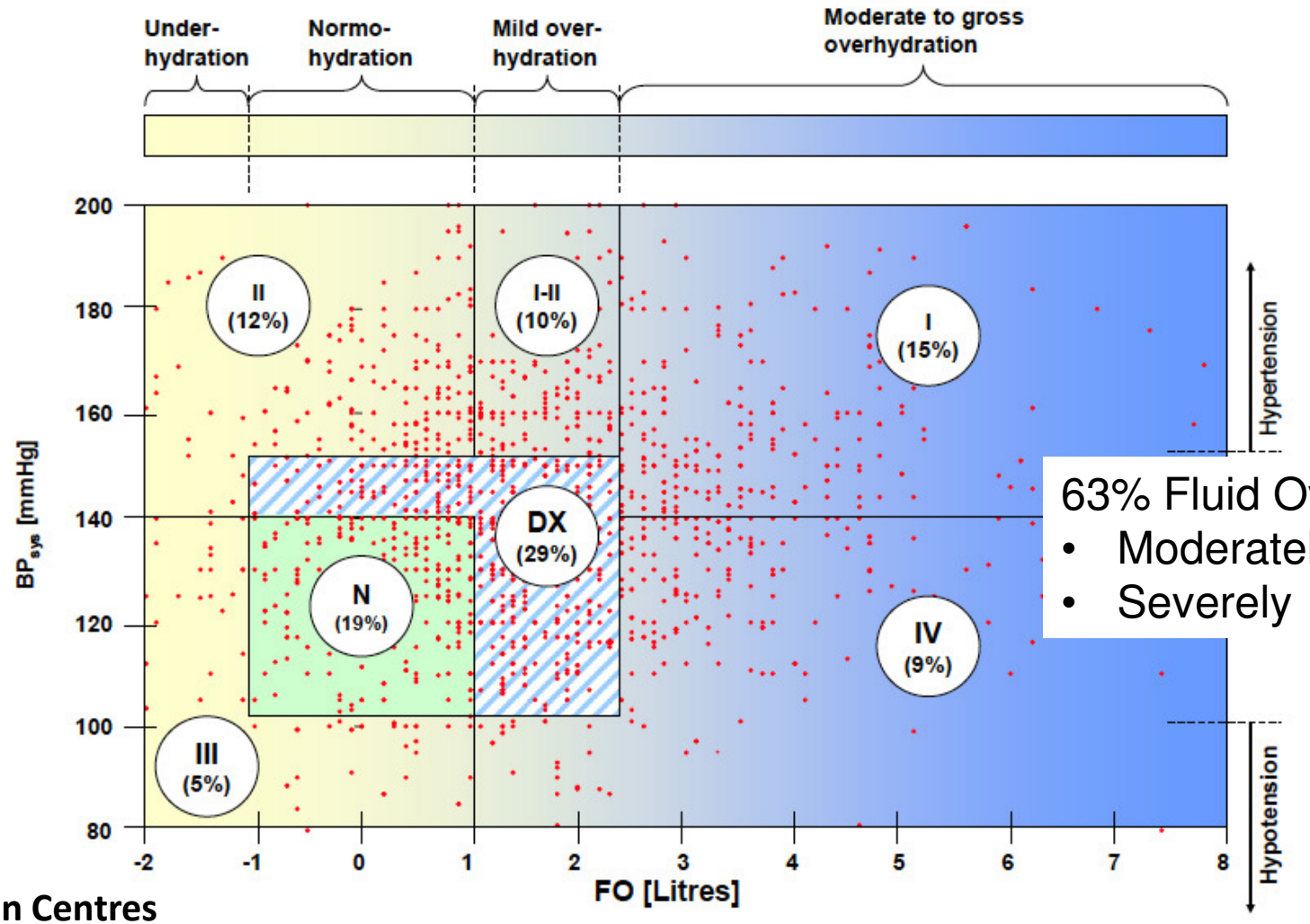
Confounding factors : ECF overload and/or myocardial abnormalities ?



ANP
BNP
NT-ProBNP
Copeptin
…



EC Fluid Status in HD Patients
Bioimpedence MultiFrequency (BCM)

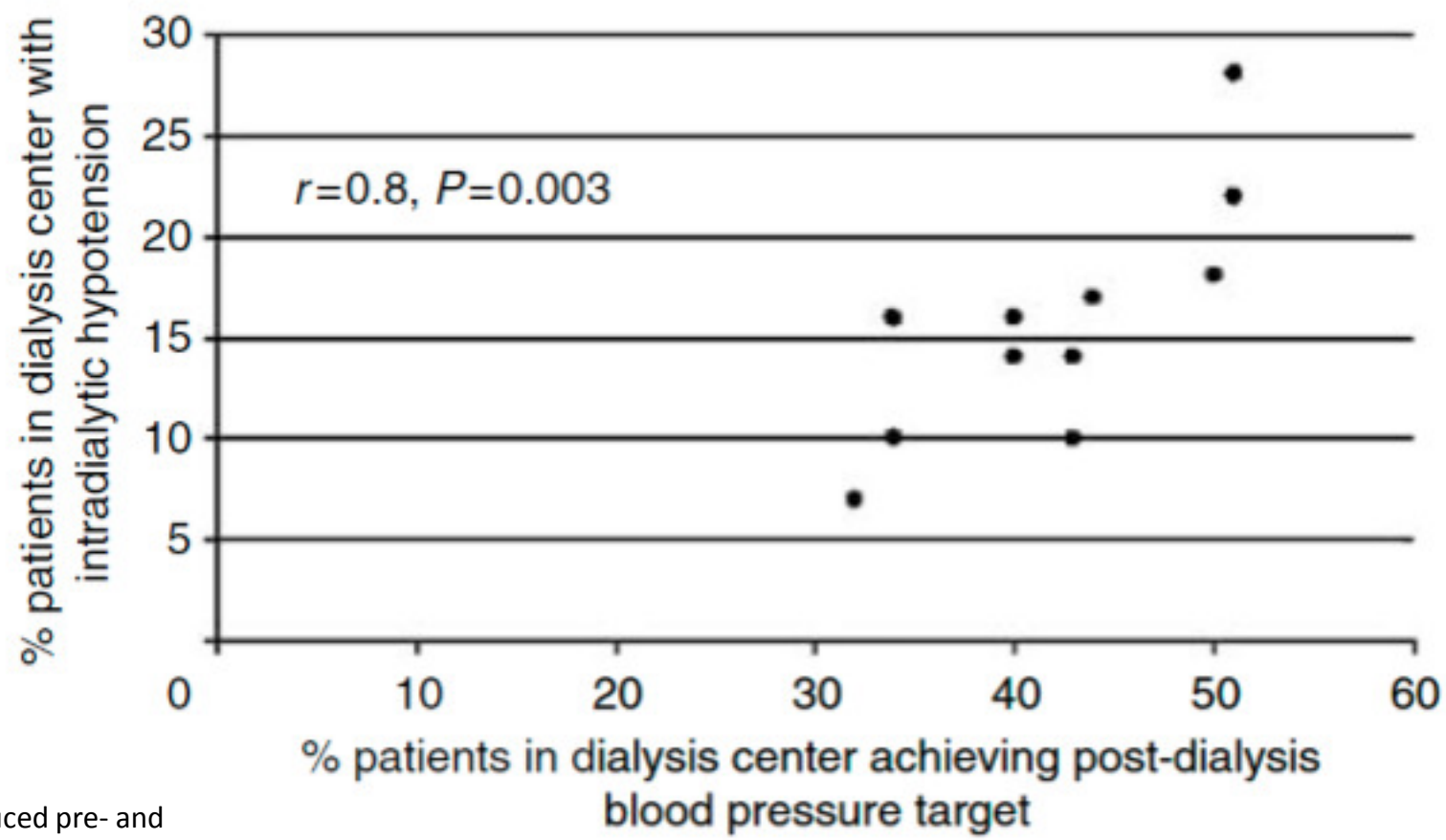


63% Fluid Overload
- Moderately 39%
- Severely 24%

NephroCare 22 European Centres
1500 Prevalent **Hemodialysis** patients

Wabel P et al, *ERA-EDTA* 2012 Poster

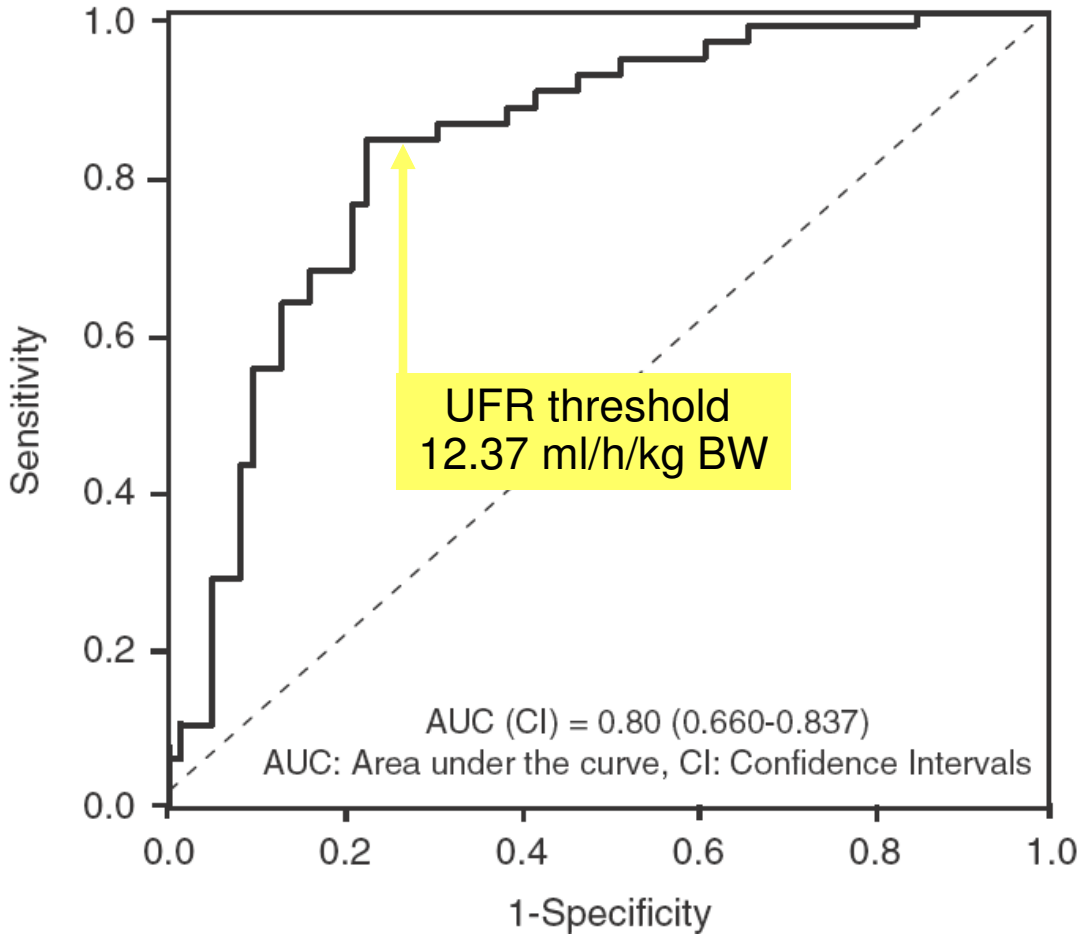
Achieving Dry Weight and Post-Dialysis Blood Pressure Target Increases Incidence of IDH



UK Renal Association introduced pre- and postdialysis target **BP <140/90 & <130/ 80mmHg**.
Audit Greater London - 2630 HD patients
Symptomatic IDH requiring fluid resuscitation

Davenport A et al, *Kidney Int* 2008;73:759

High UFR is associated with an increased risk of mortality at 5 year

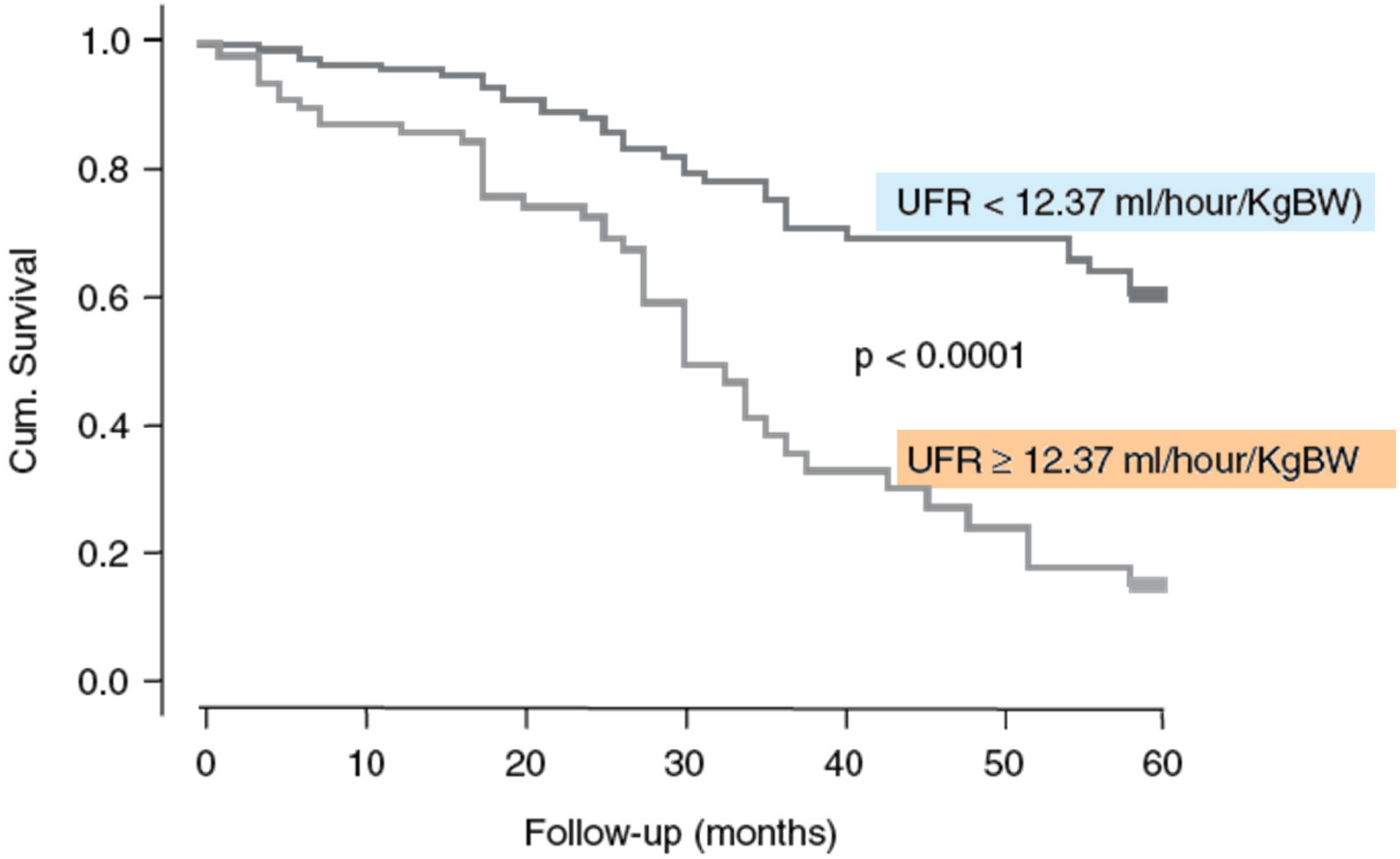


5 year prospective observational multicentre study

287 prevalent CKD HD patients (65 M, 122 F)
1 January 2000 to 31 December 2005
BW 62±13Kg; Kt/V 1.27±0.13; PCRn 1.11±0.20g/kg/d

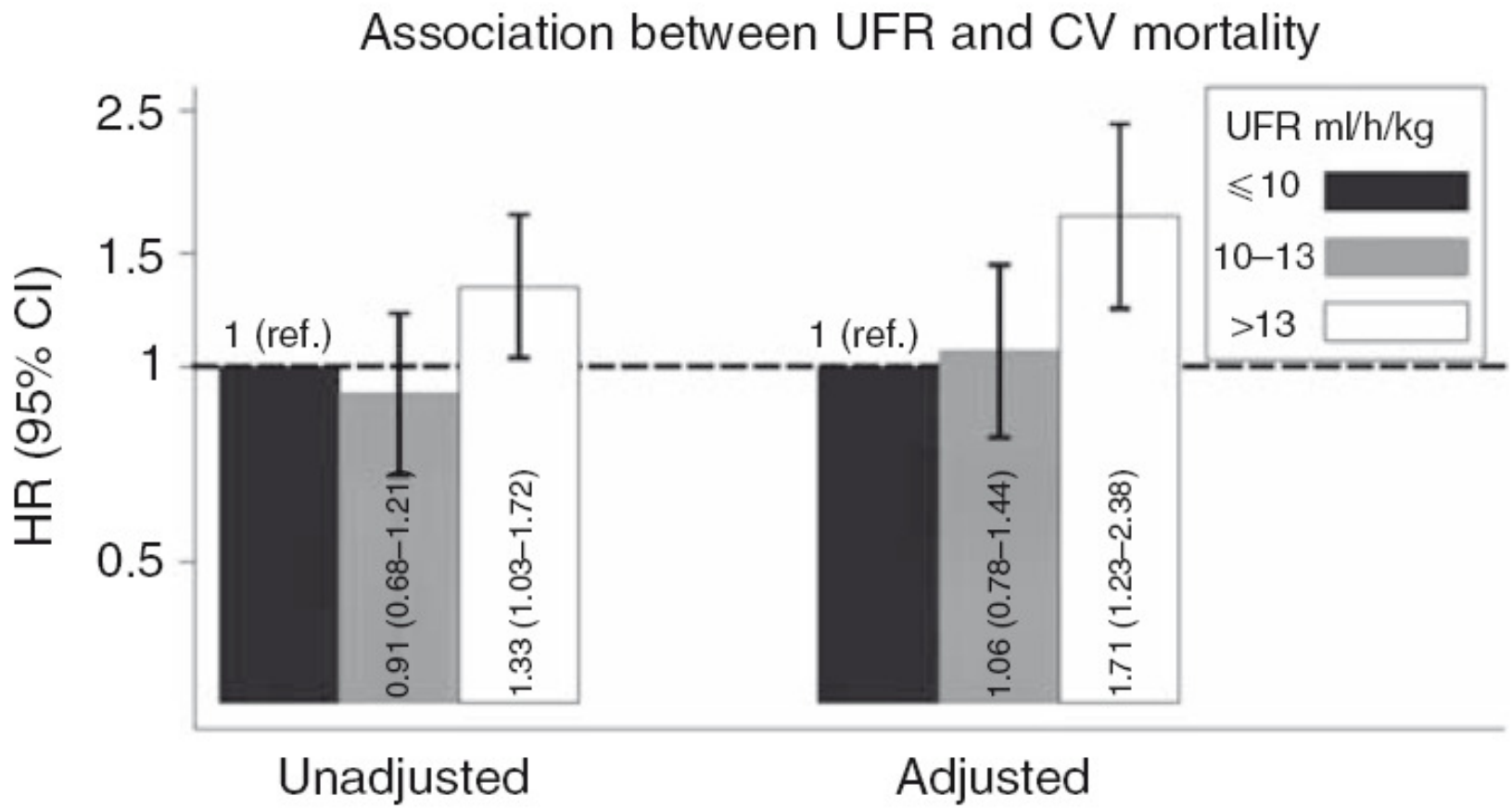
Movilli E et al, *Nephrol Dial Transplant* 2007; 22: 3547-3552

High UFR is associated with an increased risk of mortality



Movilli E et al, *Nephrol Dial Transplant* 2007; 22: 3547-3552

Ultrafiltration Rate and CV Mortality:
High UFR >13ml/h/kg is Associated with Higher CV Mortality



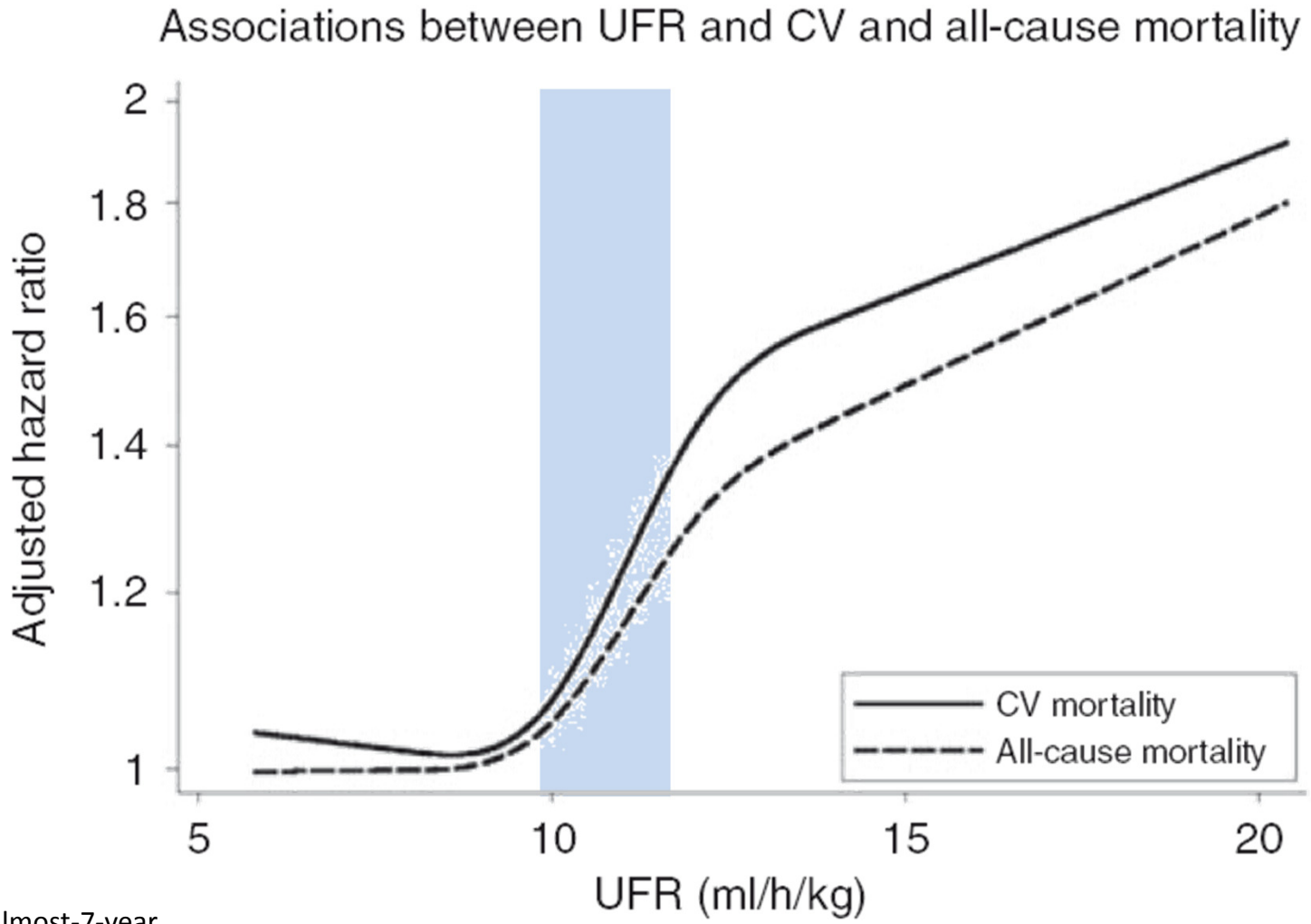
Hemodialysis Study, an almost-7-year
Randomized clinical trial of 1846 patients

HEMO Study

Flythe JE et a. *Kidney Int* 2011;79, 250–257

Ultrafiltration Rate and CV Mortality:

UFR>10ml/h/kg is Associated with Increased CV and All-Cause Mortality



Hemodialysis Study, an almost-7-year
Randomized clinical trial of 1846 patients

HEMO Study

Flythe JE et a. *Kidney Int* 2011;79, 250–257

Severe hypotensive episodes are responsible for repetitive cardiac insults and cardiac stunning

Hypoxia – Anaerobic metabolism
Enzyme induction
Metabolic adaptation
Altered gene expression
Protein abnormalities

Intradialytic Hypotension

Cardiac ischemia and Stunning

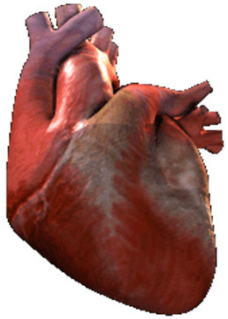
Functional hibernation

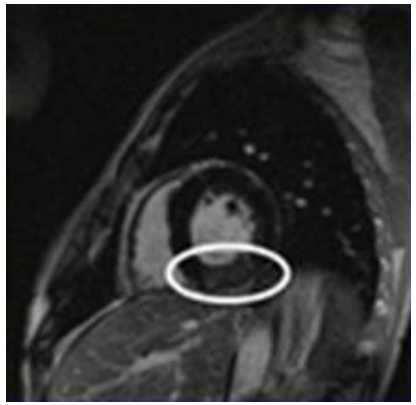
x Repetitive Episodes

Structural hibernation

Myocardial cell dedifferentiation

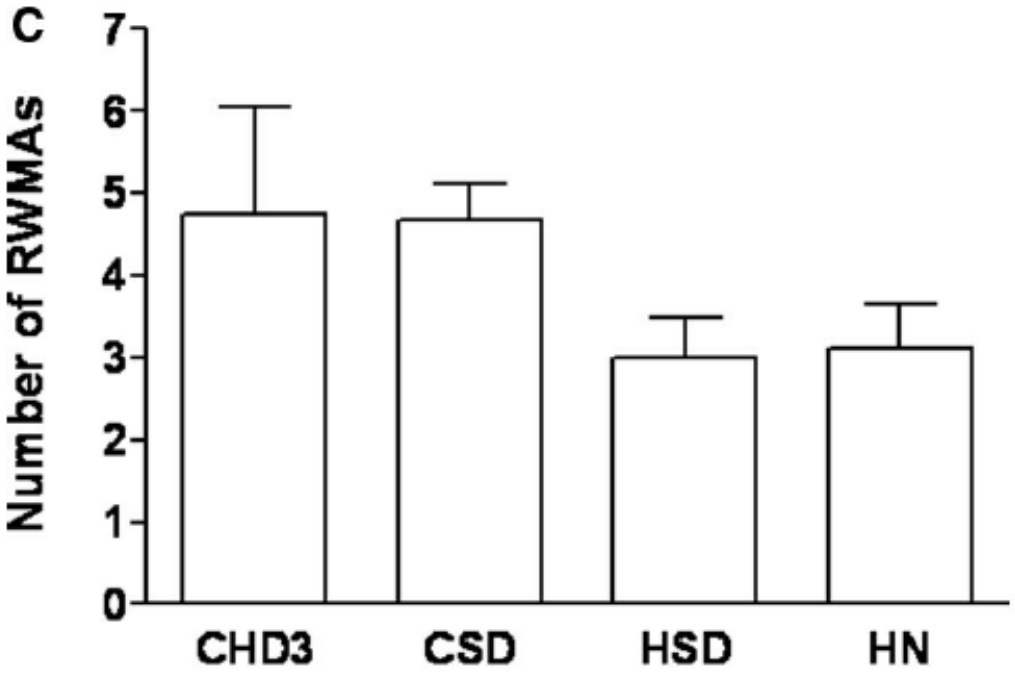
Cardiac Stunning

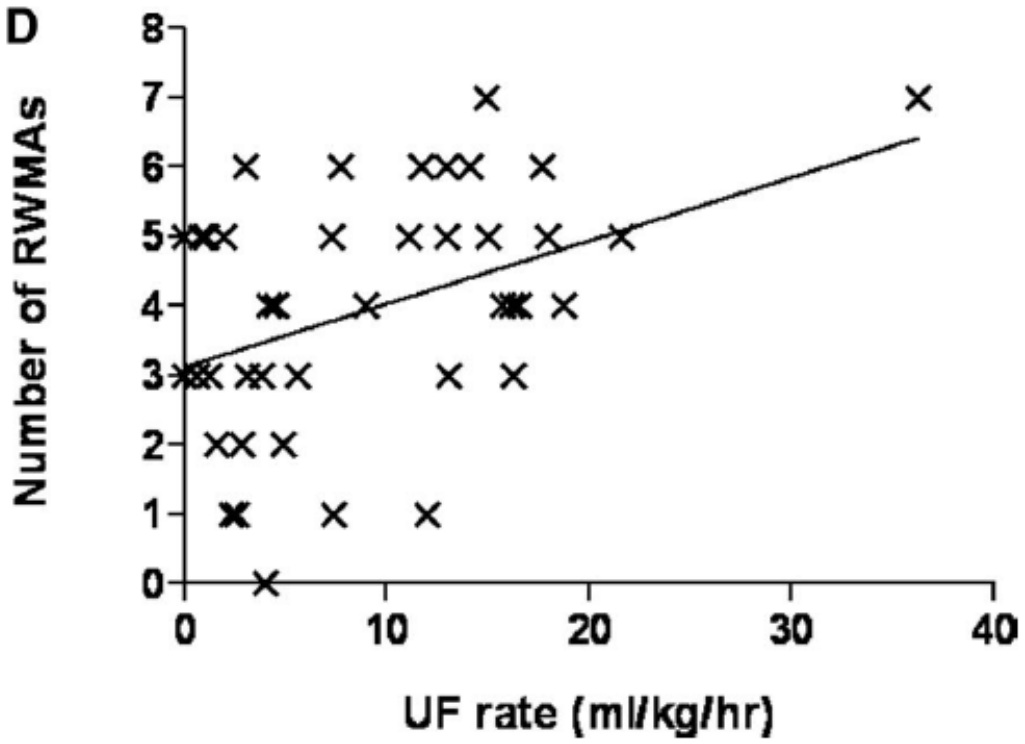




Burton JO et al, *Clin J Am Soc Nephrol* 2009; 4:914-920

Frequent Hemodialysis Schedules Are Associated with Reduced Levels of Dialysis-induced Cardiac Injury

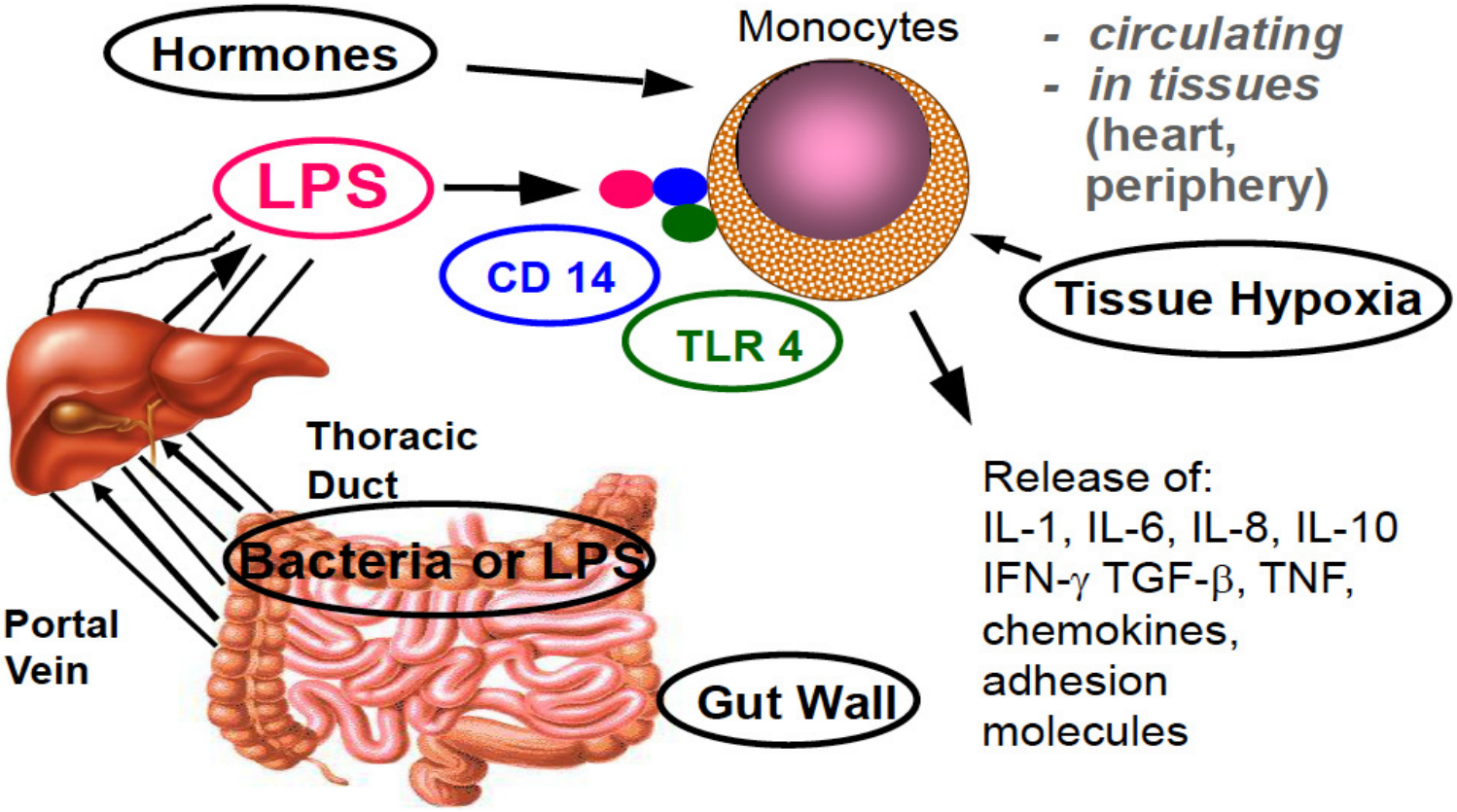




Jefferies H et al. *Clin J Am Soc Nephrol* 2011; 6: 1326–1332

Repetitive gut ischemia contributes to inflammation

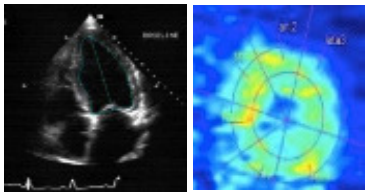
Gut ischemia - Translocation



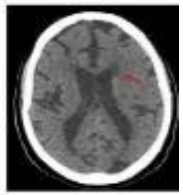
Clinical and Subclinical Manifestations of Hemodynamic Instability

Intra Dialytic Hypotension

- Cardiac Stunning
- Leuko -araiosis
- Gut Trans -location
- Distal Necrosis
- Inflam -mation



Burton JO et al.
CJASN 2009

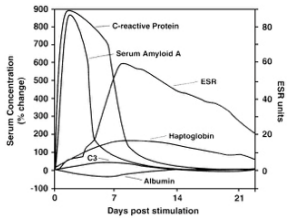


McIntyre CW et al.
JASN 2014

Jefferies HJ et al
Nephron Clin Pract. 2014

Games FL et al,
Nephron Clin Pract. 2013

Stenvinkel P et al.
NDT 2002



McIntyre CW et al.
CJASN 2011

Outlook of the Presentation

1. Sodium & fluid volume homeostasis in CKD5 HD patient
   - Basics of physiology – Challenges for nephrologist & care giver
2. Intradialytic hypotension:
   - Definition – Frequency – Causes – Consequences
3. Sodium & fluid management in HD
   - Diffusive/Convective Na
   - Ultrafiltration
4. **Preventing intradialytic hypotension**
   - **Means: diet, residual kidney function, hemodialysis, time**
   - **Stepwise approach**
5. Take home message

Restore Sodium Mass Balance in HD Patient

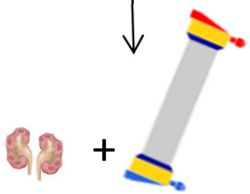
↘ **Salt diet**

↘ **Dietary Intake**
50 mM/day
3g NaCl

Salt in grams	Sodium in mg x2,5	This is roughly equivalent to
1	400	Good pinch of salt
1.25	500	One-quarter of a teaspoon salt
2.3	920	One-third of a teaspoon salt
2.5	1000	Half a teaspoon salt
4	1600	¾ of a teaspoon salt
5	2000	One teaspoon salt
6	2400	1¼ teaspoons salt
10	4000	2 teaspoons salt
12	4800	2½ teaspoons salt

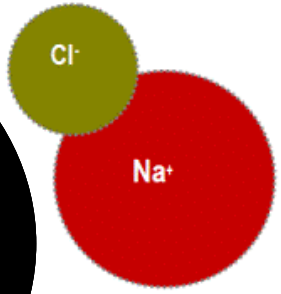
ECF Na^+
2500mM
(70%)

= **Residual Kidney Function**



Dialysis Output
100 [illegible]/hr

↗**Sodium Mass Removal**



Salt (NaCl)

Preventing Intra Dialytic Hypotension

Preserve Effective Volemia

↑Peripheral Resistance

↑Cardiac Output

↑Ejection Fraction
Heart Rate

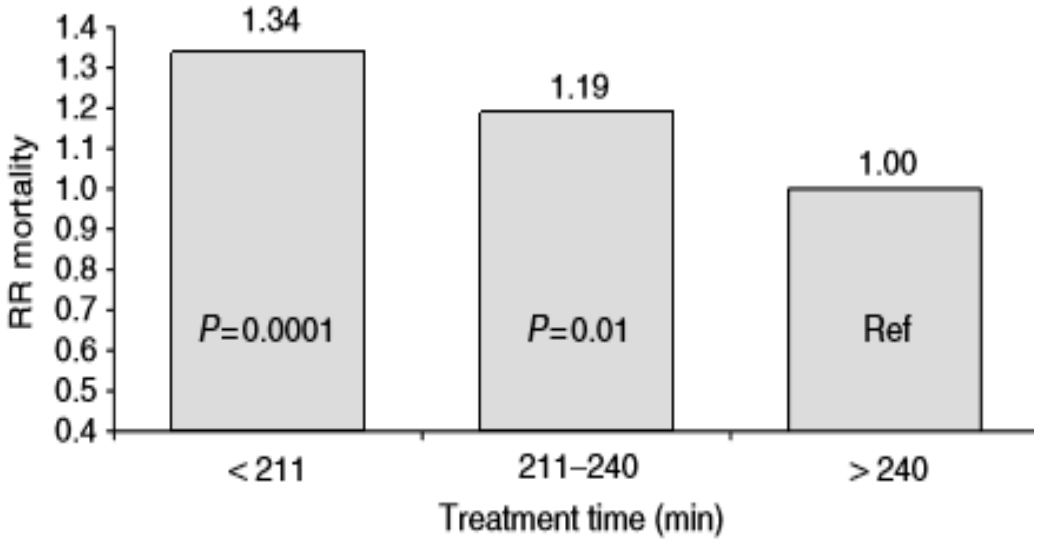
↑Vascular Tone (Art/Ven)

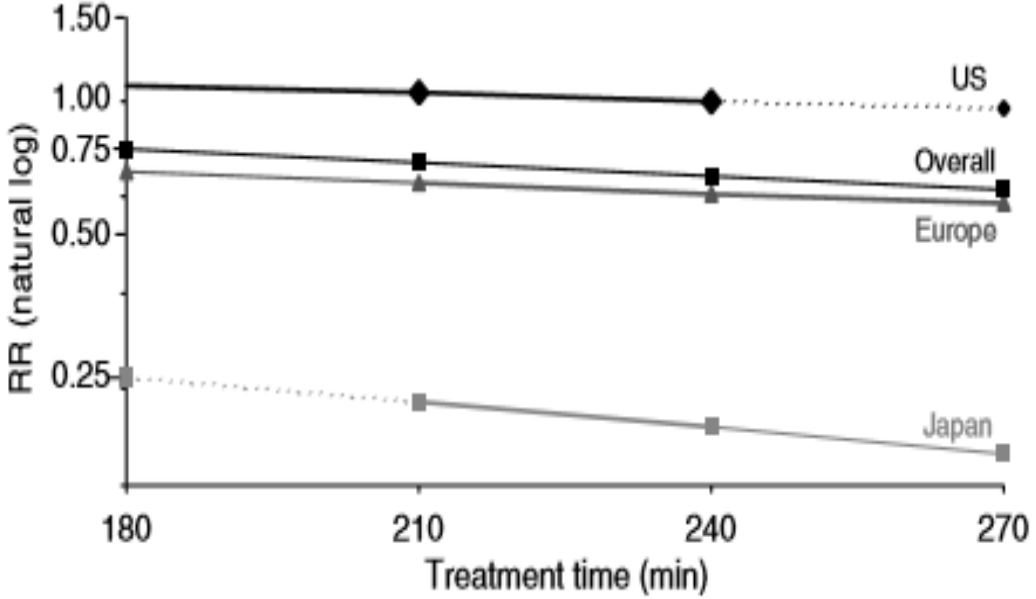
↑Refilling Rate

↓UF Rate

↑ Weekly Treatment Time

Longer Treatment Time is Associated with Lower UFR and Better Survival

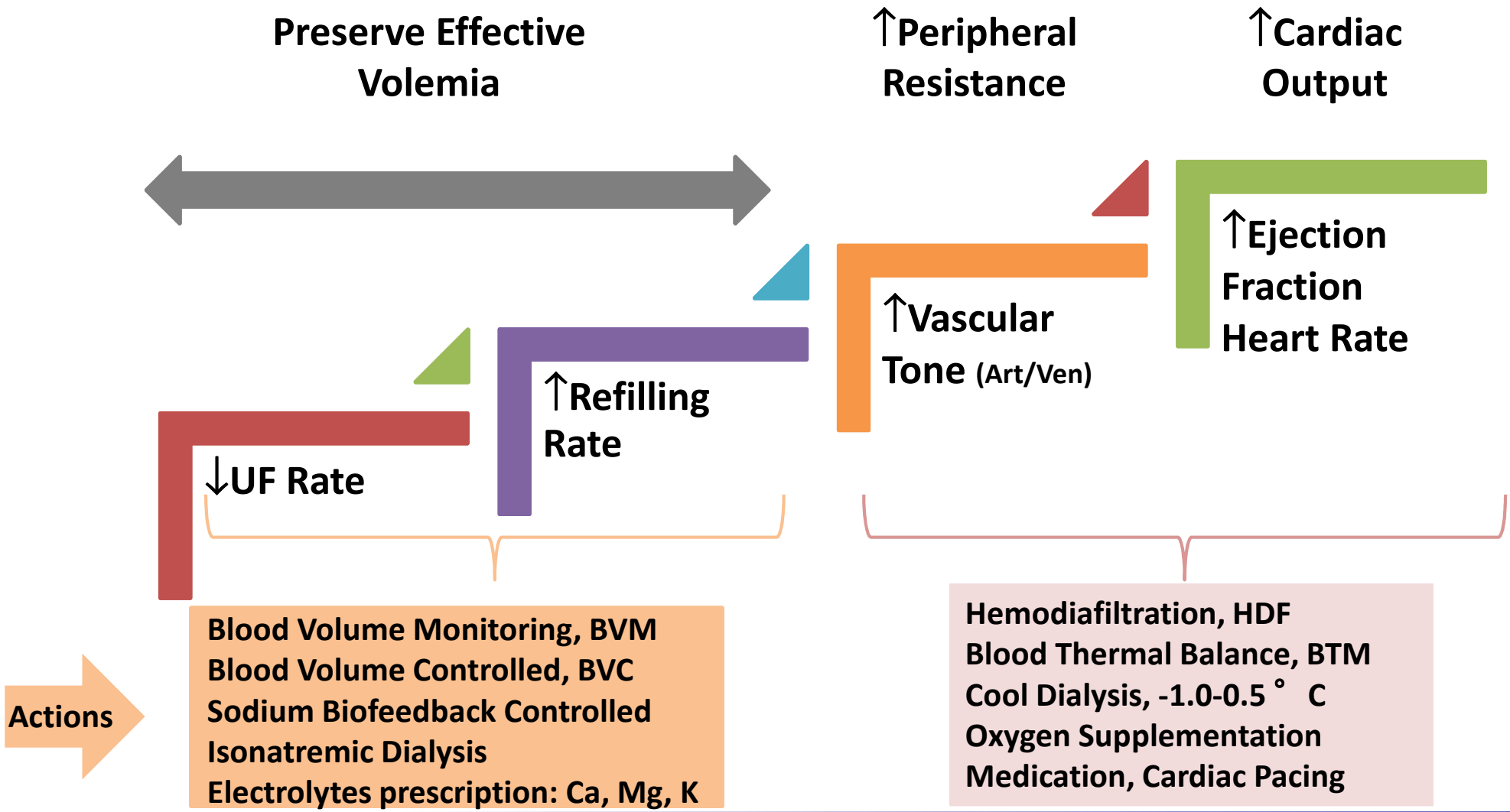




DOPPS

Saran R et al, *Kidney Int.* 2006; 69, 1222-122

Preventing Intra Dialytic Hypotension



Hemodynamic Tolerance Is Improved By HDF
Prospective Controlled Study

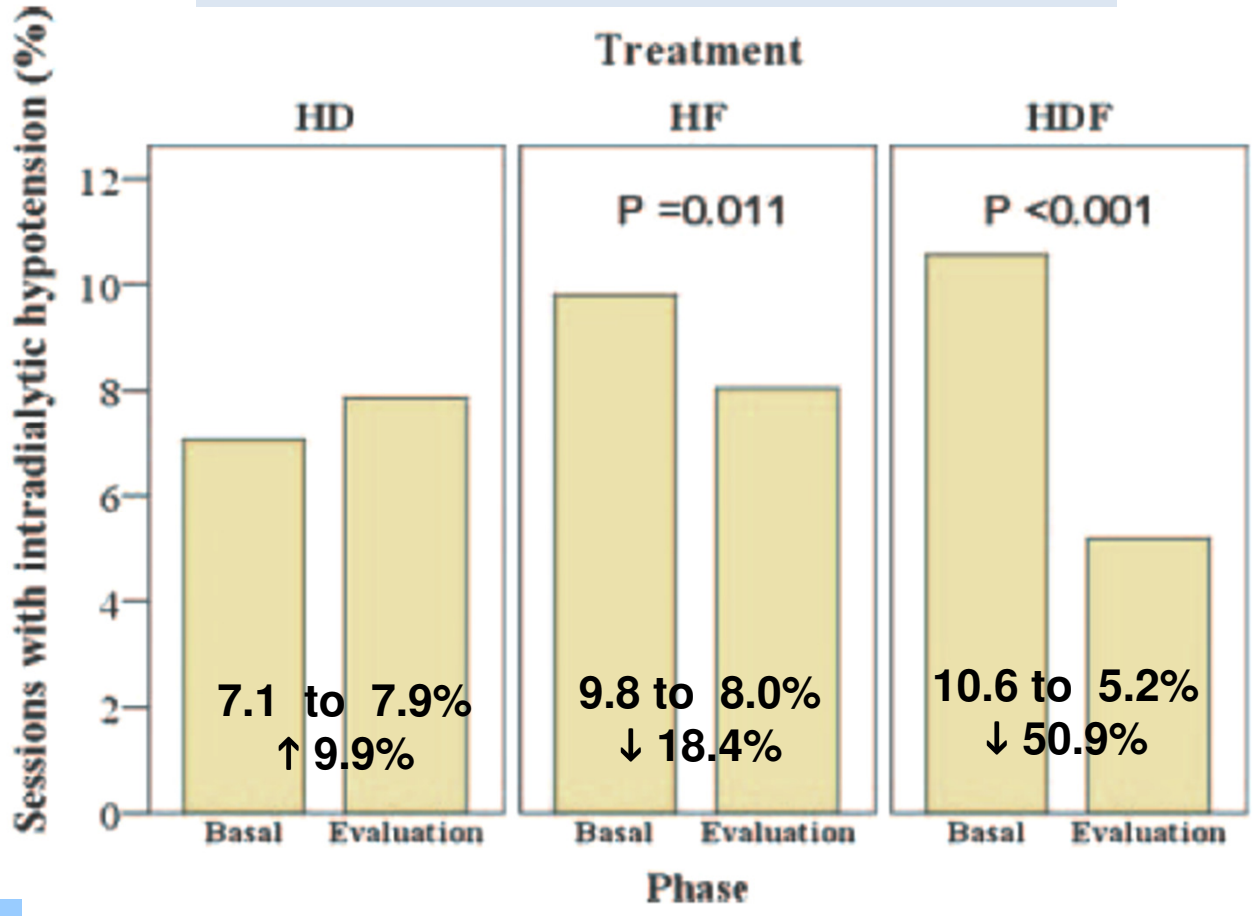
Condition	HFHD (Baseline)	On-line HDF			
		6 months	1 year	2 years	3 years
Hypotension	20.2 ± 17.1	10.4 ± 17.6	11.8 ± 16.1	10.0 ± 13.8	12.4 ± 16.1
Hypertension	2.9 ± 4.7	2.2 ± 7.7	2.4 ± 5.7	0.1 ± 0.4	0.9 ± 2.1
Muscle cramp	7.8 ± 9.5	5.3 ± 7.7	2.0 ± 2.1	3.0 ± 3.7	1.9 ± 2.3
Headache	1.7 ± 2.6	1.3 ± 3.2	0.4 ± 1.1	0.4 ± 1.1	0.3 ± 0.9

Prospective Controlled Cohort Study
Thailand Monocenter Study
22 pts - HDHF/HDF

Tiranathanagul K et al. *Ther Apher Dial* 2009; 13: 56-62

Hemodynamic Tolerance Is Improved By HDF
Randomized Controlled Study

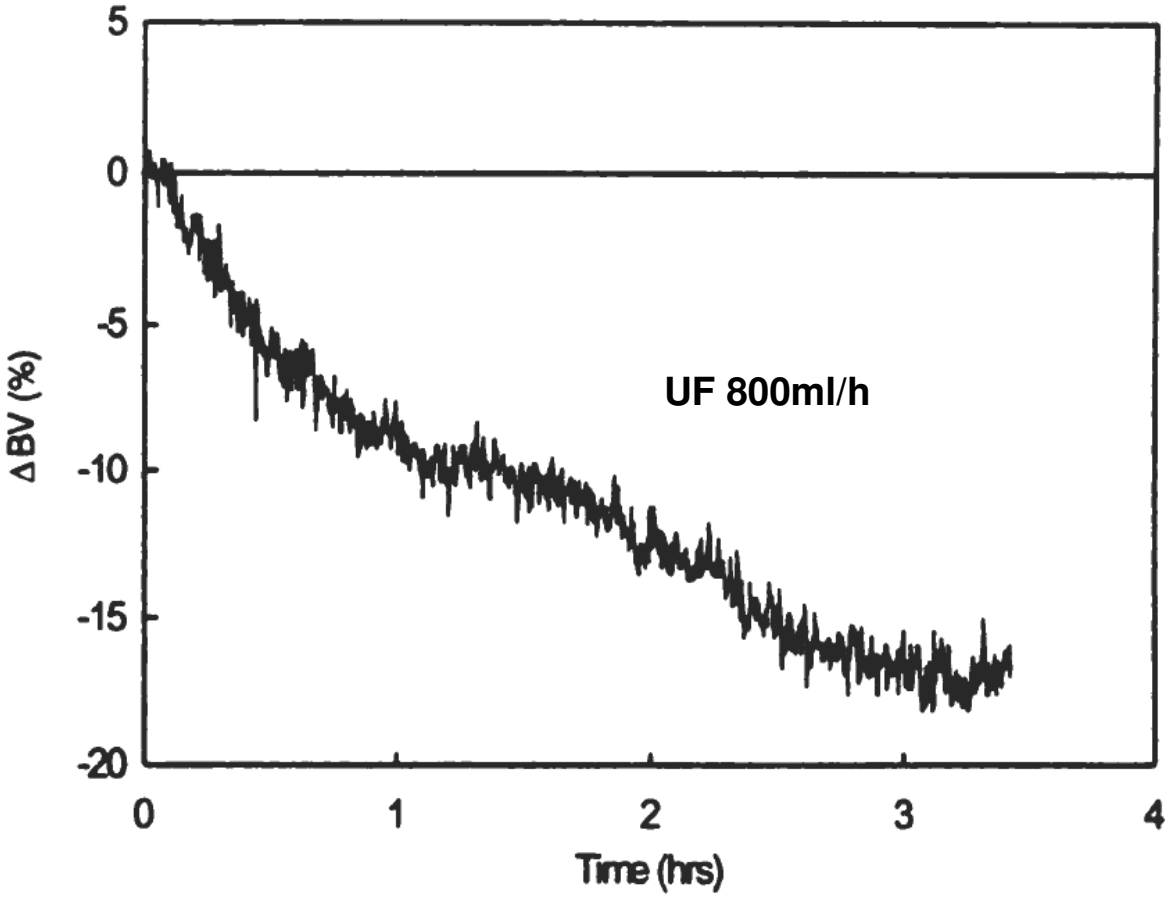
Total incidence of ISH 7.5% 28950 sessions



Italian Multicentric Study RCT
LFHD, HF, HDF Ratio 2/1/1

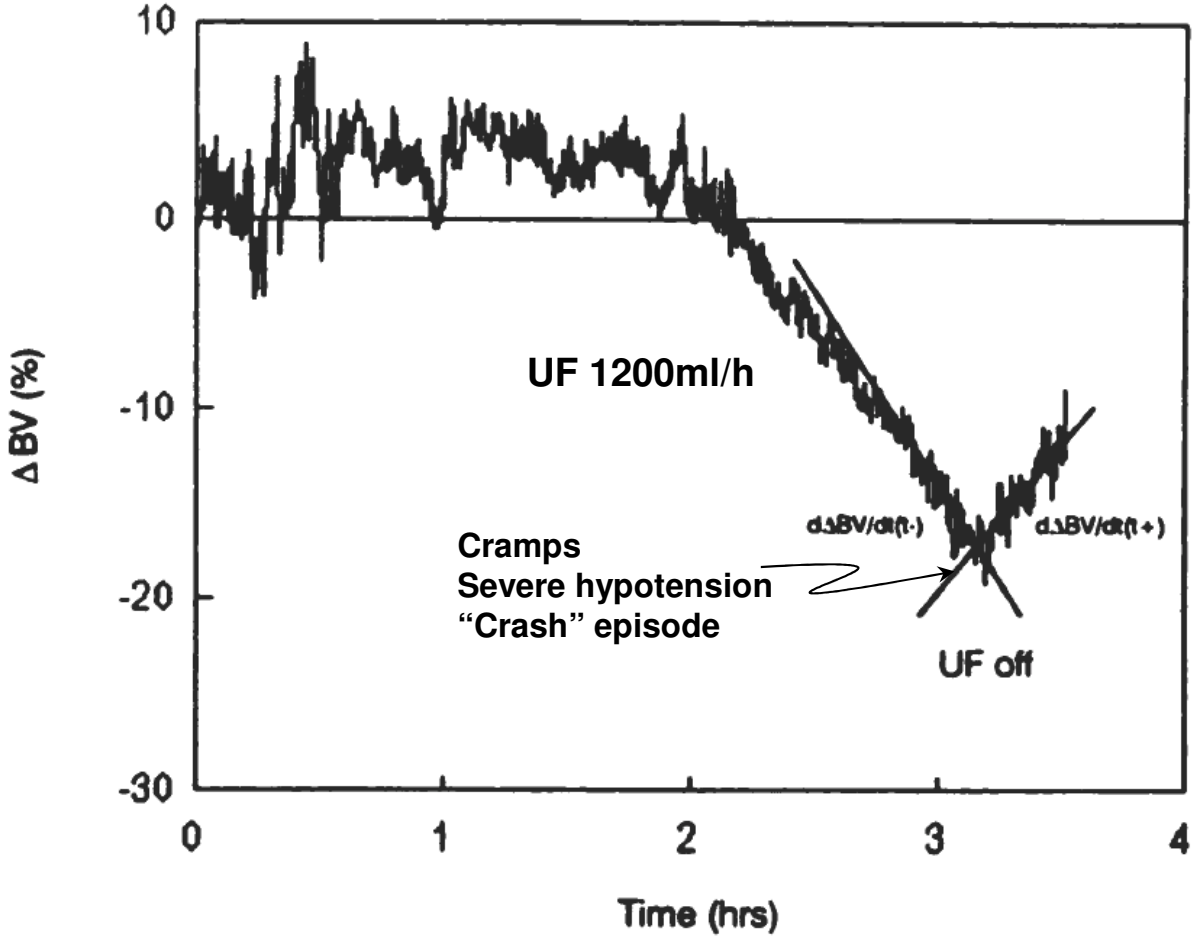
Locatelli F et al, *J Am Soc Nephrol* 2010; 21:1798-1807

Residual Blood Volume Monitoring
Probing Refilling Rate Capacity



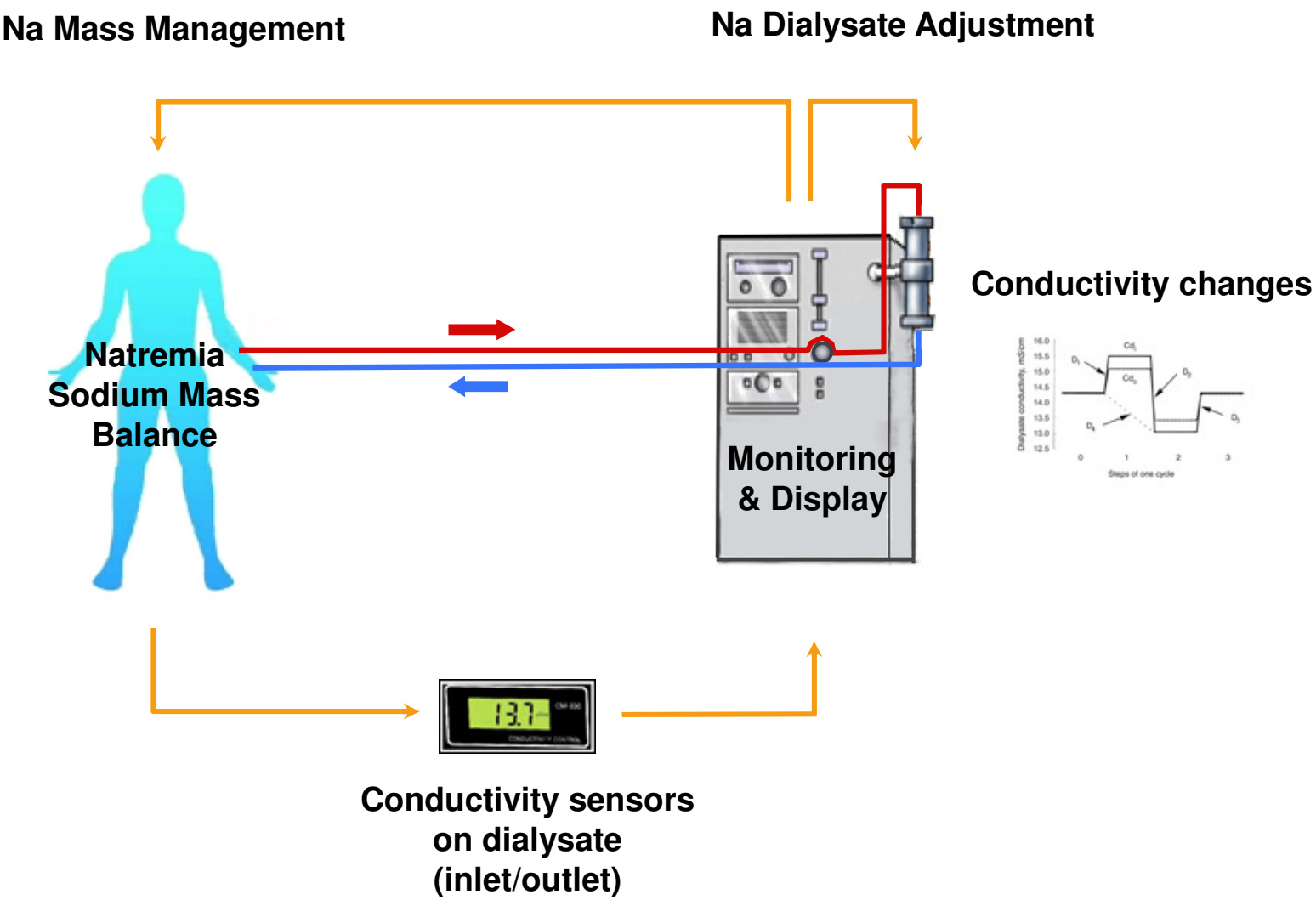
Leypoldt JK et al, *J Am Soc Nephrol* 1995; 6: 214-219

Residual Blood Volume Monitoring
Defining Individual Critical Volume

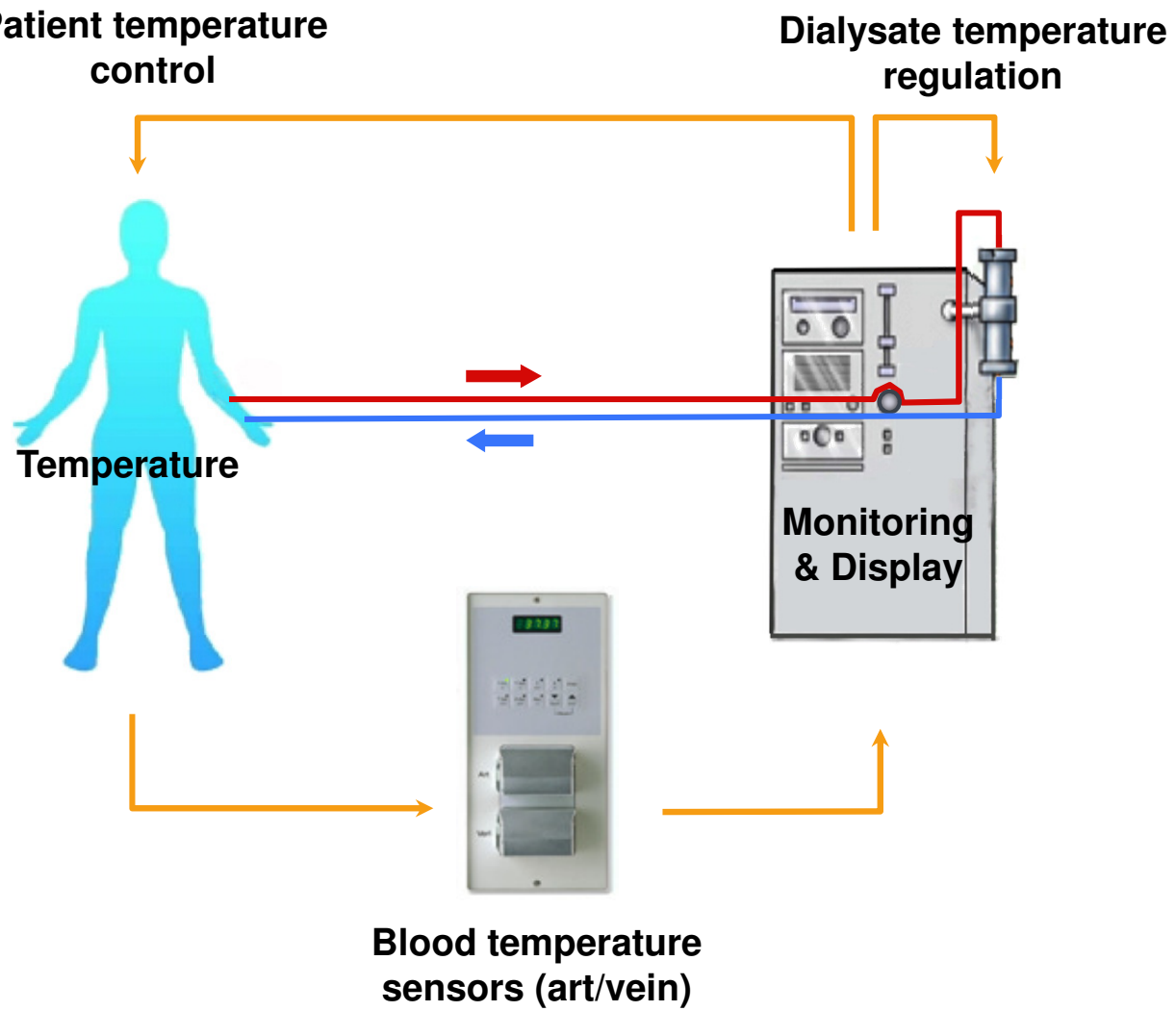


Leypoldt JK et al, *J Am Soc Nephrol* 1995; 6: 214-219

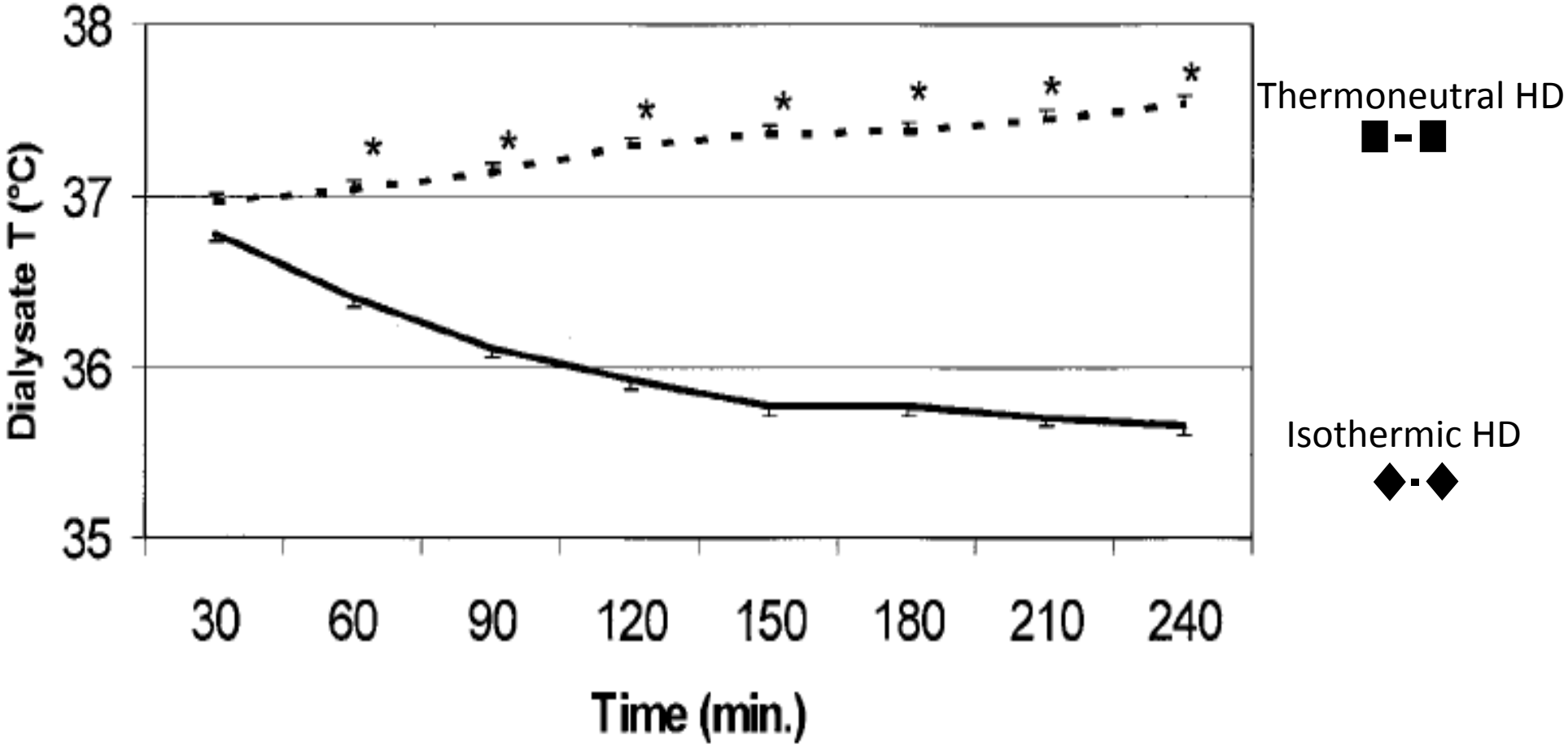
Sodium Mass Balance & Osmolality Control



Thermal Balance Control

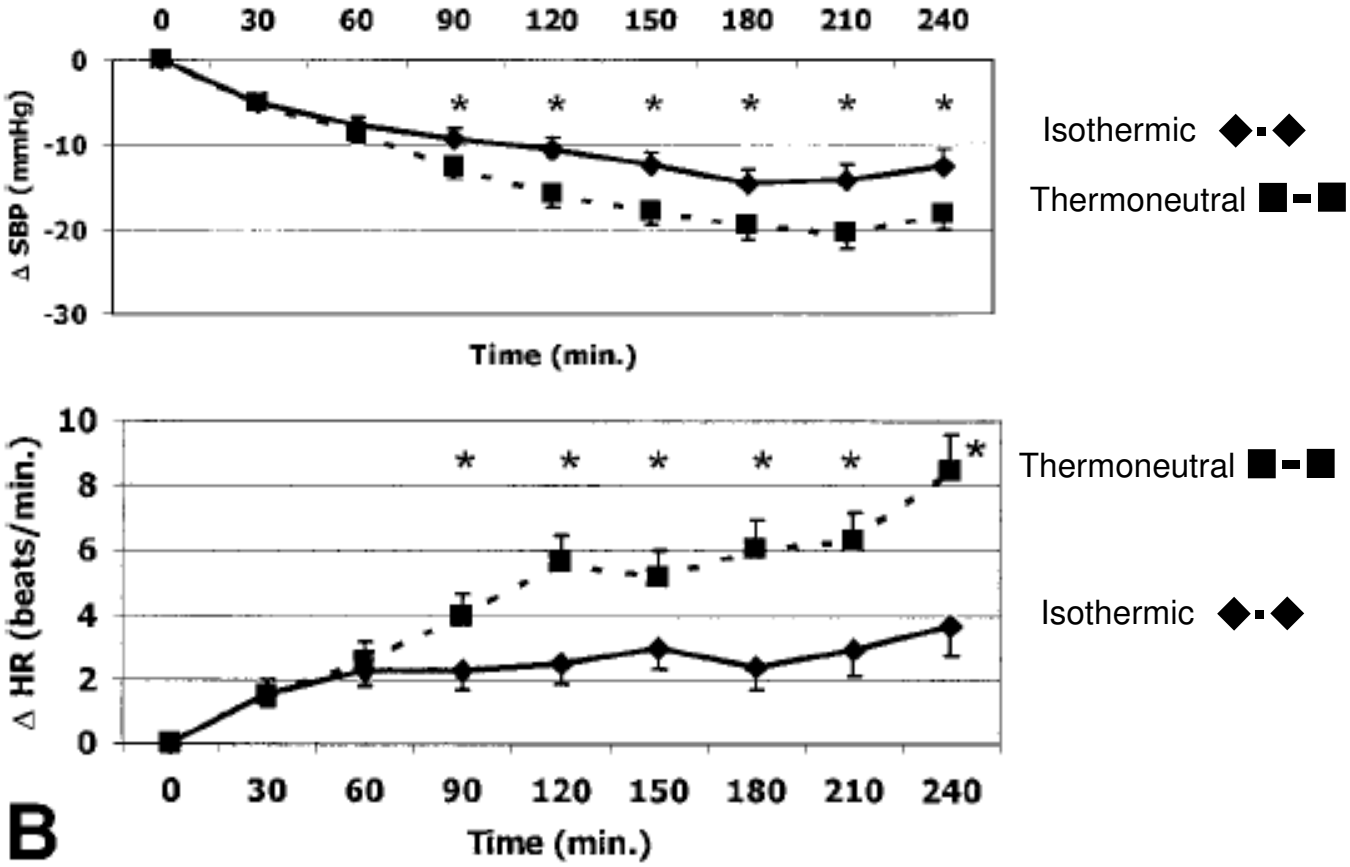


Thermoneutral balance leads HD patient to gain calories and to vasodilation



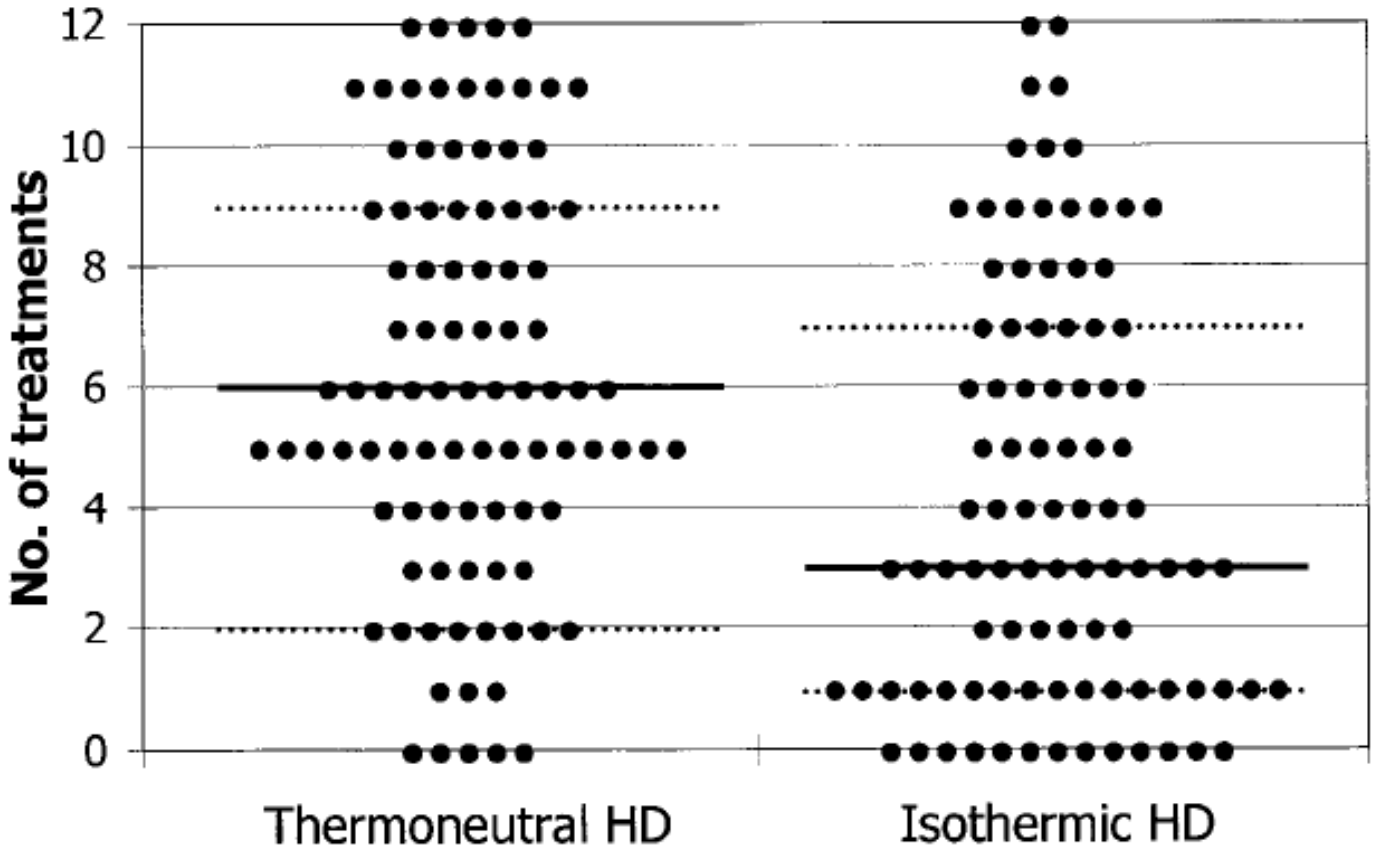
Maggiore Q et al, *Am J Kidney Dis* 2002; 40: 280-290

Changes in blood pressure (systolic) and heart rate according to thermal balance profile



Maggiore Q et al, *Am J Kidney Dis* 2002; 40: 280-290

Incidence of IDH Is Significantly Reduced During Isothermic HD



Maggiore Q et al, *Am J Kidney Dis* 2002; 40: 280-290

Preservation of Blood Pressure In HD Depends on Thermal Balance and Energy Mass Transfer

	Treatment modality	Treatments with hypotension/all treatments (%)	T_{art} 0 min (°C)	ΔT_{av} (°C)	Min BV (%)	ET (W)
Study A	o-HDF	1/25 (4%)	36.4 ± 0.4	1.2 ± 0.3[c]	91.8 ± 3.1	−16.6 ± 4.0[e]
	HD	10/25[a] (40%)	36.5 ± 0.5	0.4 ± 0.4[c,b]	94.0 ± 3.2[d]	−5.4 ± 5.1[b,e]
Study B	o-HDF	1/25 (4%)	36.5 ± 0.5	1.2 ± 0.3[c]	92.9 ± 4.0	−15.9 ± 1.9[e]
	Temp-HD	1/25[f] (4%)	36.5 ± 0.3	1.1 ± 0.1[c]	93.5 ± 3.8	−16.3 ± 4.2[e]

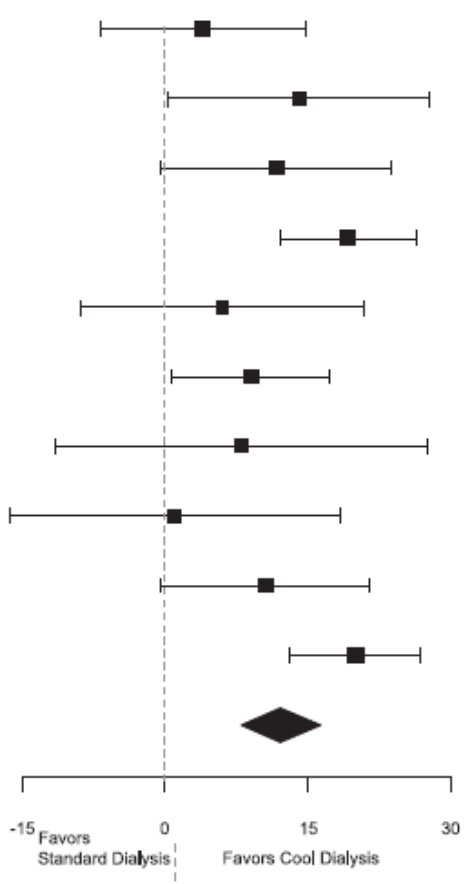
[a] $P < 0.001$, *vs* o-HDF; [b] $P < 0.0001$, *vs* o-HDF; [c] $P < 0.0001$, *vs* beginning; [d] $P < 0.005$, *vs* o-HDF; [e] $P < 0.001$, *vs* beginning; [f] $P < 0.001$, *vs* HD.

Donauer J et al, *Nephrol Dial Transplant* 2003; 18:1616-1622

Low Temperature Dialysis Reduces Intra Dialytic Hypotension

Source	Intervention	Cool Dialysis n mean(SD)	Standard Dialysis n mean(SD)	Mean Difference (95% CI)
Dheenan 2001	Fixed 35 C	10 -8 (10.82)	10 -12 (13.45)	4.00 [-6.70, 14.70]
Hegbrant 1994	Fixed 34.5 C	10 1 (14.49)	10 -13 (16.73)	14.00 [0.28, 27.72]
Hoeben 2002	Fixed 35.5 C	13 -4.8 (14.4)	13 -16.5 (16.8)	11.70 [-0.33, 23.73]
Jamil 2000	Fixed 35.5 C	7 -10.4 (4.79)	7 -29.6 (8.44)	19.20 [12.01, 26.39]
Jost 1993	Fixed 35 C	12 -6 (21.28)	12 -12 (15.52)	6.00 [-8.91, 20.91]
Kaufman 1998	BTM 35.7 C	15 4 (11.62)	15 -5 (11.62)	9.00 [0.68, 17.32]
Levy 1992	Fixed 35 C	6 8 (15.87)	6 0 (18.52)	8.00 [-11.52, 27.52]
Schneditz 1997	Fixed 35.3 C	8 -1 (14.73)	8 -2 (20.07)	1.00 [-16.25, 18.25]
van der Sande 2001	Fixed 35.5 C	12 -15.1 (13.8)	12 -25.6 (13.5)	10.50 [-0.42, 21.42]
Yu 1995	Fixed 35 C	9 6.5 (9.7)	9 -13.4 (3.6)	19.90 [13.14, 26.66]
Total				12.16 [7.94, 16.39]

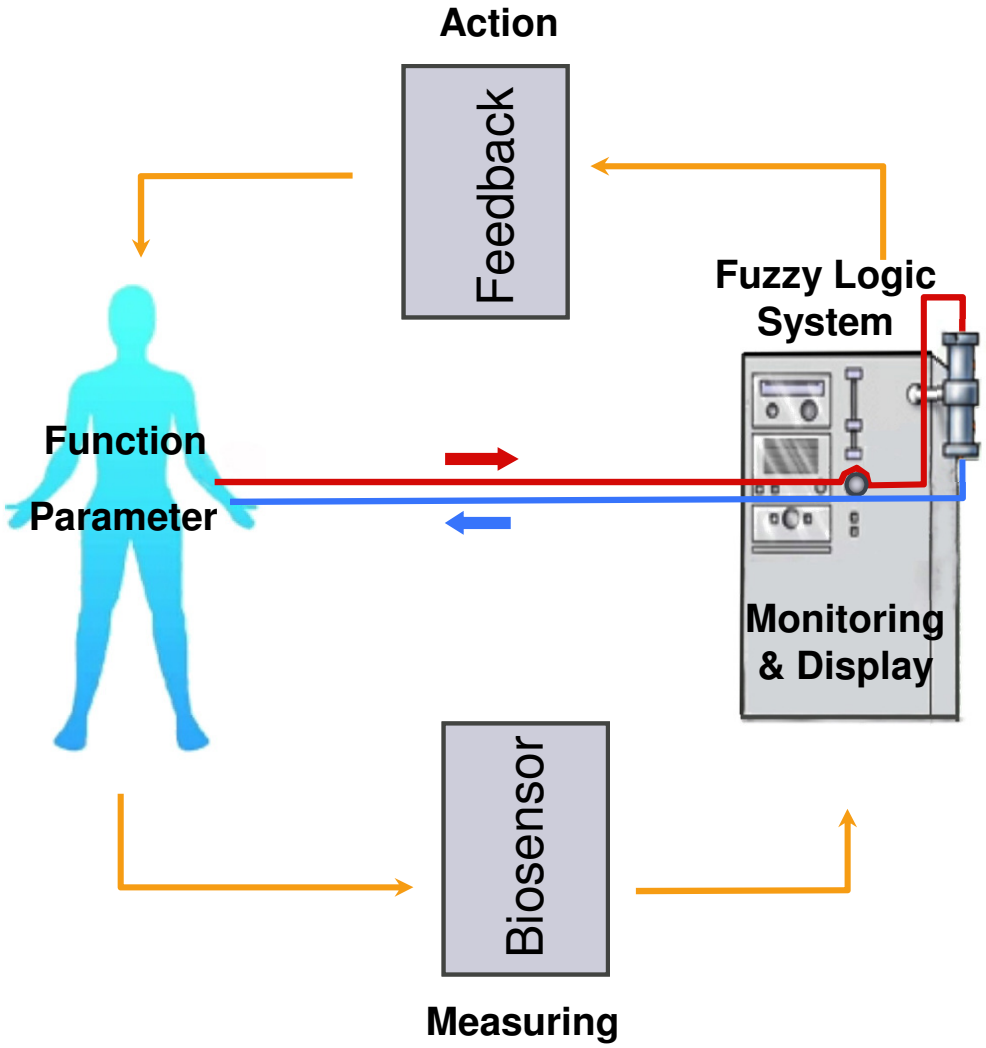
Test for heterogeneity for pooled Mean Difference: $Chi^2 = 13.67$, df = 9 (P=0.13), I^2=34%



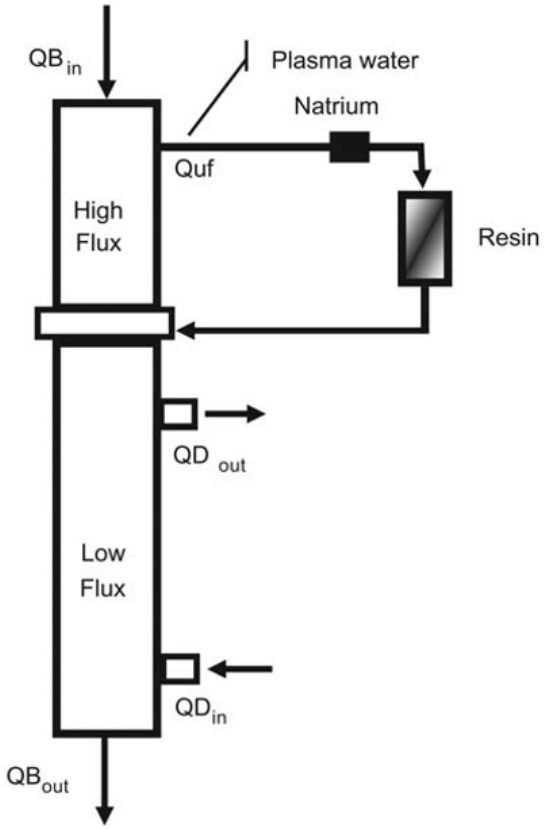
BTM, biofeedback temperature monitoring

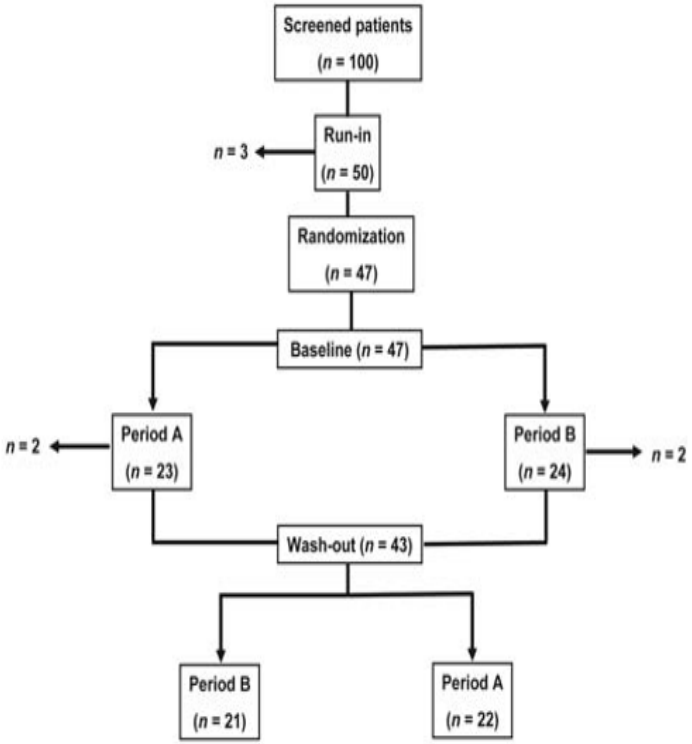
Mustafa RA et al, *Clin J Am Soc Nephrol* 2016;11: 442–457

Biofeedback systems are on the way



Effect of Plasma Sodium Biofeedback System on Intradialytic Cardiovascular Stability

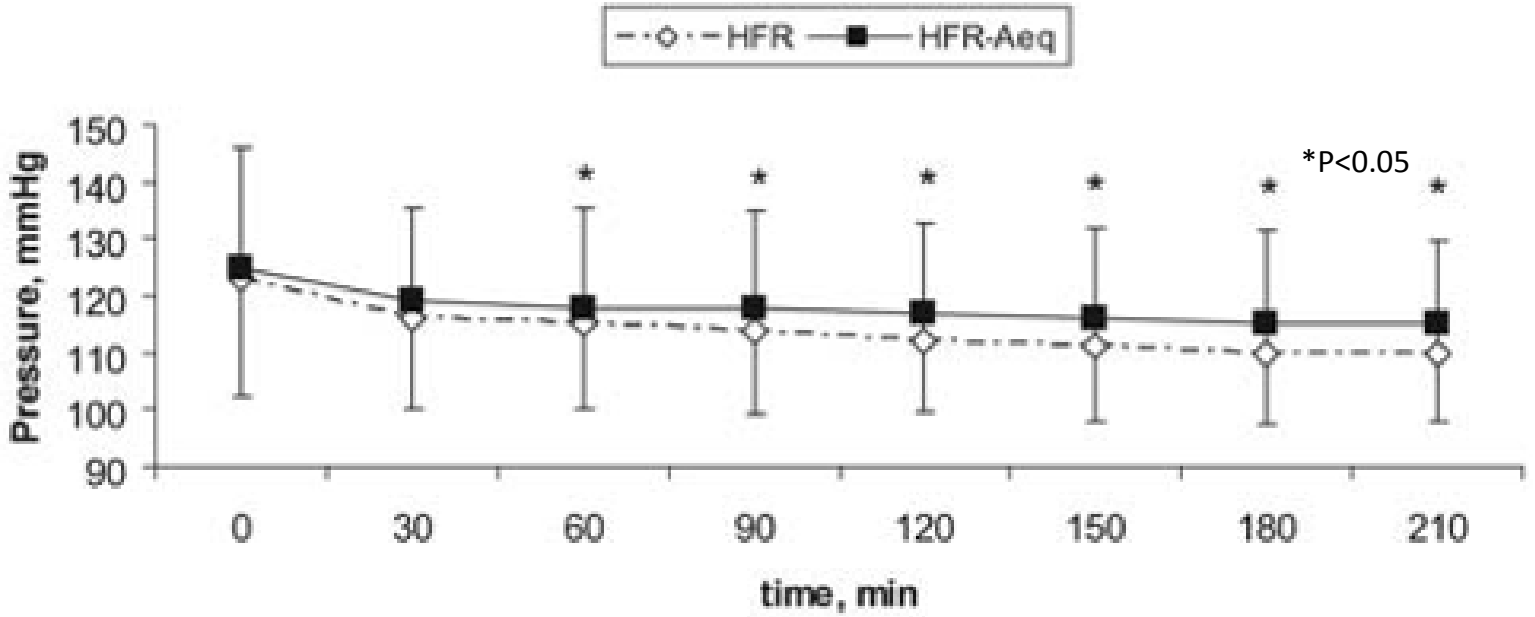




RCT Cross-Over Study
Intern. multicenter 47 HD Pats

HFR : hemofiltration with endogenous reinfusion
HFR-Aeq : Aequilibrium, HFR plus Na controlled

Effect of Plasma Sodium Biofeedback System on Systolic Blood Pressure During Treatment



RCT Cross-Over Study
Intern. multicenter 47 HD Pats

HFR : hemofiltration with endogenous reinfusion
HFR-Aeq : Aequilibrium, HFR plus Na controlled

Plasma Sodium Biofeedback System Reduces Incidence of IDH

All patients ($N = 143$)	HFR (%)	HFR-Aequilibrium (%)	Wilcoxon, P
Primary end point			
Dialysis complicated by hypotension	31 ± 4	23 ± 3	0.03
Secondary end points			
Symptomatic hypotensions	5 ± 1	3 ± 1	0.04
Intradialytic symptoms	9 ± 1	6 ± 2	0.01
Nurse interventions	22 ± 2	17 ± 3	<0.01

Outlook of the Presentation

1. Sodium & fluid volume homeostasis in CKD5 HD patient
   - Basics of physiology – Challenges for nephrologist & care giver
2. Intradialytic hypotension:
   - Definition – Frequency – Causes – Consequences
3. Sodium & fluid management in HD
   - Diffusive/Convective Na
   - Ultrafiltration
4. Preventing intradialytic hypotension
   - Means: diet, residual kidney function, hemodialysis, time
   - Stepwise approach
5. **Take home message**

Take Home Message

- Restoring and controlling **sodium and fluid mass balance** are major targets of renal replacement adequacy
- **Sodium mass removal** relies on two components: **diffusive and convective**
- **Ultrafiltration** is a surrogate of sodium mass and fluid removal
- **Intradialytic hypotension** episodes have significantly reduced over time and are now recognized as a **risk factor for CV injury**
- Sodium and fluid control is a **trade-off** between risks of **EC fluid overload and depletion**
- **Dry weight probing** requires more sophisticated tools for assessment
- **Prevention of intradialytic hypotension** is **suitable, feasible and achievable**

Sodium and Fluid Mass Balance in HD Patient

Unstable Equilibrium

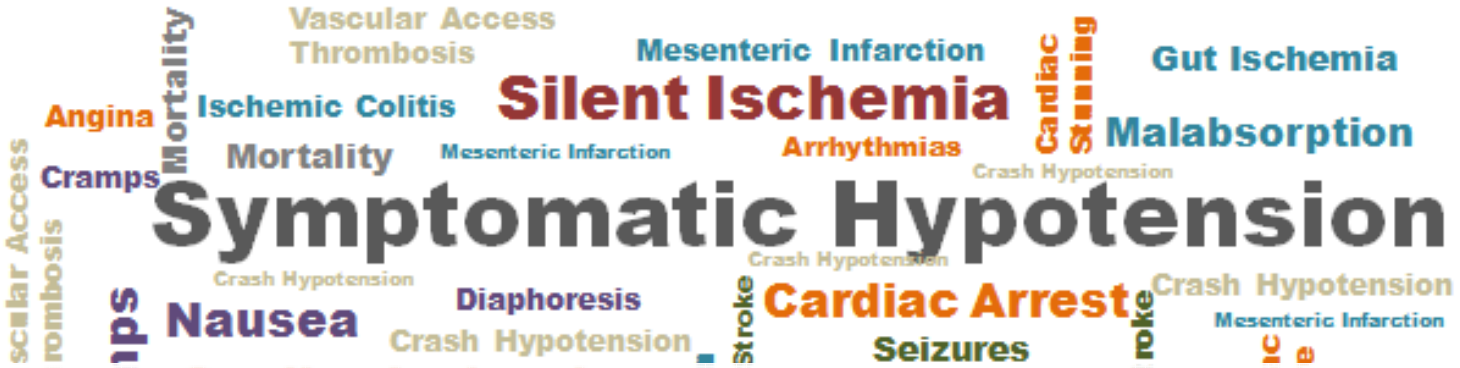
EC Fluid Overload

- Hypertension
- Left Ventricular Hypertrophy
- Lung edema
- Inflammation
- Malnutrition…

EC Fluid Depletion

- IDH
- Silent ischemic insults
- Cardiac stunning
- Gut ischemia
- Brain damage
- Liver damage…

Final Reminder



Sodium is the guilty,

Water is a passive bystander !!