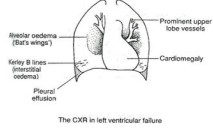


흉부 방사선 촬영



- 체액량 감소: 유용성 감소
- 체액량 과다: specific sign
 - 상엽혈관의 확장(dilated upper lobe vessels), 심비대, 간질부종, 폐동맥 확장, 흉막삼출액, 폐포 부종, 상대정맥 돌출, Kerley선
 - 방사선 촬영에서 이상소견과 임상적인 효과 간에 수시간의 지연이 있을 수 있어 치료반응을 평가할 때 주의해야 한다
 - 방사선 촬영을 이동식으로(portably) 하였을 때, 체액량 과다의 민감도는 현격히 떨어진다.

Dry weight?

Table 4 Dry weight clinical assessment data

	ECV overload	ECV depletion
(1) Case history	Excessive salt intake Dyspnea, headache	Diarrhea, vomiting, diuretics Postural dizziness, cramps
(2) Signs	No BP postural drop Increased BP Weight increase Full neck veins Edema	BP postural drop Hypotension Decreased weight Flat neck veins No edema
(3) X-Ray	Increased cardio-thoracic index	Normal cardio-thoracic index
(4) Lab data	Decreased hematocrit, total proteins and serum albumin	Increased hematocrit, total proteins and serum albumin

BP=blood pressure; ECV=extracellular volume.

Clinically apparent edema > interstitial volume increased by 2.5-3L

Diagnostic accuracy of each parameter for the presence of volume overload in patients presenting with dyspnea to the emergency department

Finding	Sensitivity (%)	Specificity (%)	Positive LR (95% CI)	Negative LR (95% CI)
Symptoms				
Paroxysmal nocturnal dyspnea	41	94	2.6 (1.5-4.5)	0.70 (0.54-0.91)
Orthopnea	50	77	2.2 (1.2-3.9)	0.65 (0.45-0.92)
Edema	51	76	2.1 (0.92-5.0)	0.64 (0.39-1.1)
Dyspnea on exertion	84	34	1.3 (1.2-1.4)	0.48 (0.35-0.67)
Fatigue and weight gain	31	70	1.0 (0.74-1.4)	0.99 (0.85-1.1)
Cough	36	61	0.93 (0.70-1.2)	1.0 (0.87-1.3)
Physical exam				
Third heart sound	13	99	11 (4.9-25.0)	0.88 (0.63-0.94)
Hepatjugular reflux	24	96	6.4 (0.81-51.0)	0.79 (0.62-1.0)
Jugular venous distention	39	92	5.1 (3.2-7.9)	0.66 (0.57-0.77)
Rales	66	78	2.8 (1.9-4.1)	0.51 (0.37-0.70)
Any murmur	27	90	2.6 (1.7-4.1)	0.81 (0.73-0.90)
Lower extremity edema	50	78	2.3 (1.5-3.7)	0.64 (0.47-0.87)
SBP < 100 mmHg	6	97	2.0 (0.60-6.6)	0.97 (0.91-1.0)
Fourth heart sound	5	97	1.6 (0.47-5.5)	0.98 (0.93-1.0)
SBP > 150 mmHg	28	73	1.0 (0.69-1.6)	0.99 (0.84-1.2)
Wheezing	22	58	0.52 (0.38-0.71)	1.3 (1.1-1.7)
Ascites	1	97	0.33 (0.04-2.9)	1.0 (0.99-1.1)

JAMA 2005;294:1944 Korean J Med 2011;60:325-345

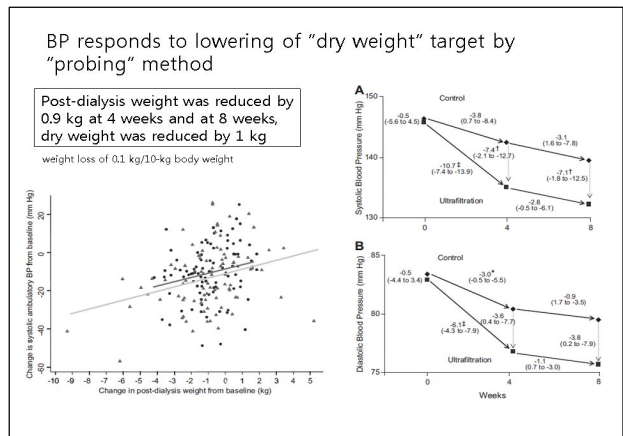
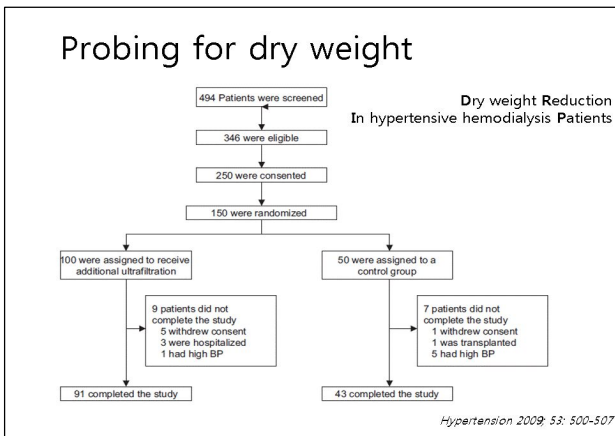
Dry weight

- **The reduction of BP to hypotensive levels during UF, represented the achievement of a dry weight status**

Arch Intern Med 1967;120:153-167

 - In a patients receiving antihypertensive medication?
- **The post-dialysis weight at which the patient is and remains normotensive until the next dialysis in spite of the interdialytic fluid retention without anti-hypertensive medication**

Kidney Int 17: 571-576, 1980



Intradialytic symptoms

Table S1: Proportion of patients with intradialytic signs and symptoms of hypotension

Symptom/Sign	Change from baseline					
	Baseline prevalence	-2 to 0 weeks	0-2 weeks	2-4 weeks	4-6 weeks	6-8 weeks
Cramps						
Control	14.5 (8.6 to 20.3)	-1.5 (-7.7 to 4.7)	-4.2(-10.6 to 2.1)	-1.7 (-8.2 to 4.8)	-4.5 (-11.1 to 2.1)	
Ultrafiltration	10.2 (6.0 to 14.3)	5.6 (1.2 to 10.1)*	11.8 (7.4 to 16.3)*	8.3 (3.8 to 12.9)*	6.0 (1.4 to 10.5)*	
Difference	4.3 (-1.4 to 2.9)	7.1 (-0.5 to 14.8)	16.1 (8.3 to 23.9)*	10.1 (2.2 to 18.0)	10.1 (2.5 to 18.5)*	
Dizziness						
Control	4.7 (1.0 to 8.3)	-2.3 (-6.7 to 2.0)	-2.7 (-7.0 to 1.7)	-2.1 (6.6 to 2.3)	-2.4 (-7.0 to 2.1)	
Ultrafiltration	3.4 (0.8 to 6.0)	2.2 (-0.8 to 5.3)	5.1 (2.0 to 8.2)*	6.7 (3.5 to 9.8)*	6.0 (2.8 to 9.1)*	
Difference	-1.3 (-5.7 to 3.2)	4.6 (-0.6 to 9.9)	7.7 (2.4 to 13.1)*	8.8 (3.3 to 14.2)*	8.4 (2.9 to 13.9)*	
Hypotension						
Control	12.1 (5.9 to 18.2)	-0.6 (-6.9 to 5.7)	-0.6 (-6.9 to 5.8)	4.0 (-2.4 to 10.5)	0.6 (-0.6 to 7.2)	
Ultrafiltration	11.6 (7.2 to 16.0)	6.1 (1.6 to 10.5)*	9.6 (5.2 to 14.1)*	13.2 (8.6 to 17.8)*	13.2 (8.6 to 17.7)*	
Difference	-0.4 (-8.0 to 7.1)	6.7 (-1.0 to 14.4)	10.2 (2.5 to 18.0)*	9.2 (1.2 to 17.1)*	12.6 (4.6 to 20.6)*	
Ultrafiltration stopped						
Control	13.3 (7.5 to 19.1)	-2.5 (-9.0 to 4.0)	-2.7 (-9.3 to 3.9)	2.0 (-4.7 to 8.7)	1.8 (-5.0 to 8.6)	
Ultrafiltration	14.1 (10.0 to 18.2)	5.8 (1.1 to 10.4)*	13.3 (8.7 to 18.0)*	9.6 (4.8 to 14.3)*	10.2 (5.5 to 14.9)*	
Difference	0.7 (-6.4 to 7.8)	8.3 (0.0 to 24.1)*	16.1 (8.0 to 24.1)*	7.6 (-0.6 to 15.8)	8.4 (0.1 to 16.7)*	
Bolus saline						
Control	9.7 (5.1 to 14.3)	-0.3 (-5.6 to 5.1)	-3.7 (-9.1 to 1.7)	-0.8 (-4.7 to 6.2)	0.0 (-0.5 to 0.6)	
Ultrafiltration	6.4 (3.2 to 9.7)	5.3 (1.6 to 9.2)*	7.3 (3.5 to 11.1)*	9.3 (5.4 to 13.1)*	8.4 (4.5 to 12.3)*	
Difference	-3.3 (-8.9 to 2.3)	5.6 (-0.9 to 12.1)	11.0 (4.4 to 17.6)*	8.5 (1.8 to 15.2)*	8.4 (1.9 to 15.1)*	

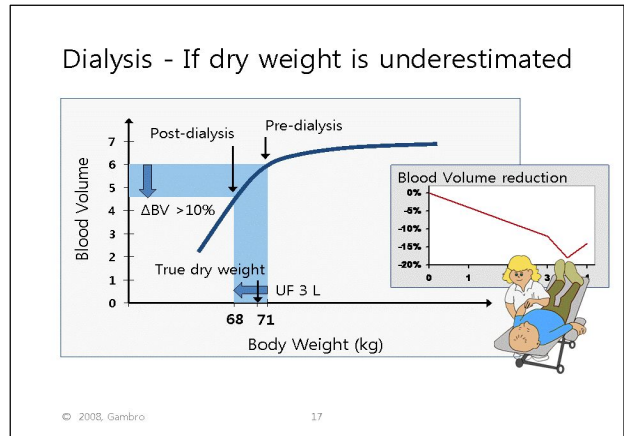
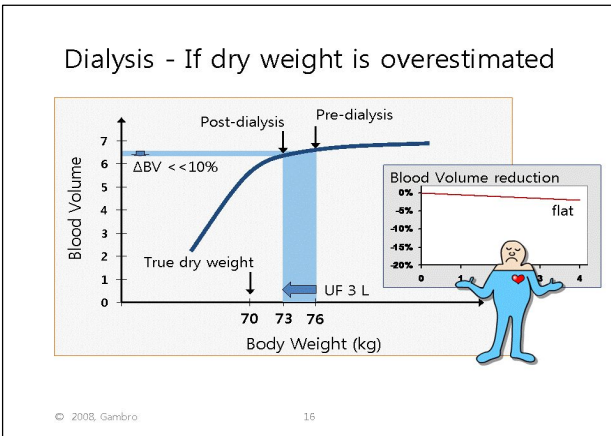
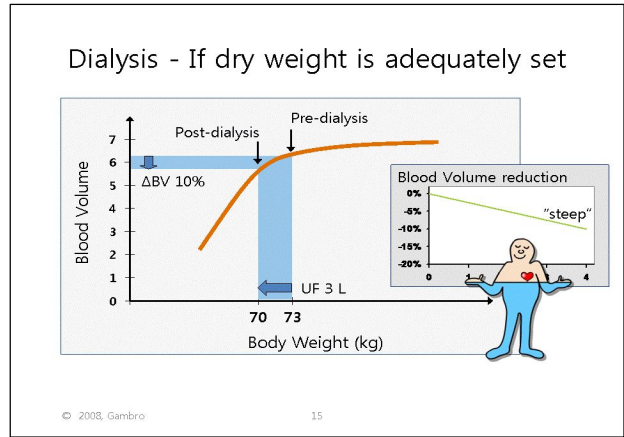
The reduction of dry weight is a simple, efficacious, and well-tolerated maneuver to improve BP control in hypertensive hemodialysis patients.

By its very nature "dry weight probing" necessarily induces an increase in adverse intradialytic symptoms, signs and interventions

Technique	Benefits	Limitations	References
Biochemical markers	Ease of use No additional labor cost Highly sensitive for the volume overloaded state Reflective of intravascular volume status	Difficult to use in heart failure, tricuspid/atrial valve disease Cannot detect the "undehydrated" state "Normal" range? Meaning of low value?	Benefits: 40,43,45,46,51,52 Limitations: 44,47-49
Vena cava diameter	Widely available Reflective of intravascular volume status Change in size correlates well with ultrafiltration volume/hemodynamic parameters	Difficult to use in heart failure Overestimates degree of dehydration postdialysis Interoperator error Highly variable/difficult to normalize to population	Benefits: 60-62 Limitations: 55,54,57,58,59
Bioimpedance	Hydric volumes correlate well with isotope dilution methods Ease of use, immediate results Reproducible/repeatable Measurement of interstitial space and ICF Immediate assessment of nutritional status Has potential to be readily normalized Continuous, hemodynamic and static/dry weight utility Sensitive in detecting the undehydrated state	Underestimates ultrafiltration volume removed from trunk Accurate measurement of ICF confounded by temperature and ion effect Accurate measurement of ECF confounded by effect of recumbency	Benefits: 74,77-79,81 Limitations: 76,82-84
Blood volume monitoring	Ease of use and understanding Allows for concomitant prevention of hypotension May be useful to screen for an inappropriately high or low dry weight	Continuous plasma volume dependent on numerous factors other than hydration of the interstitial space Measures relative volumes only Interpatient variability	Benefits: 93-95 Limitations: 89

Principle of blood volume sensor

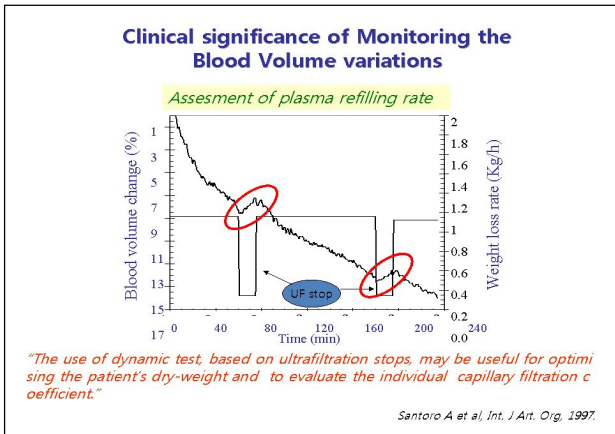
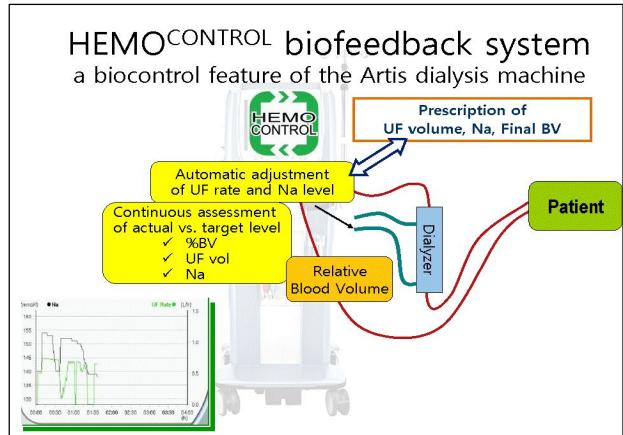
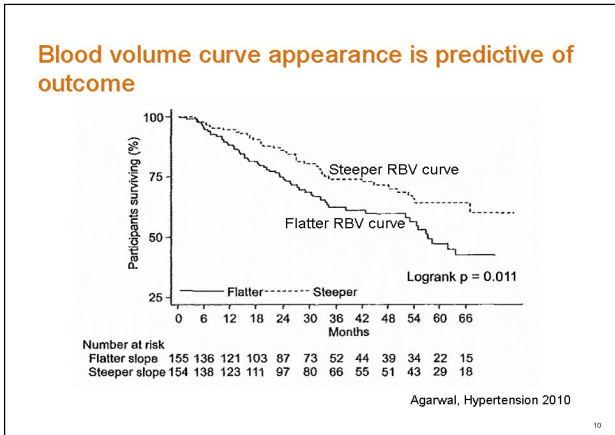
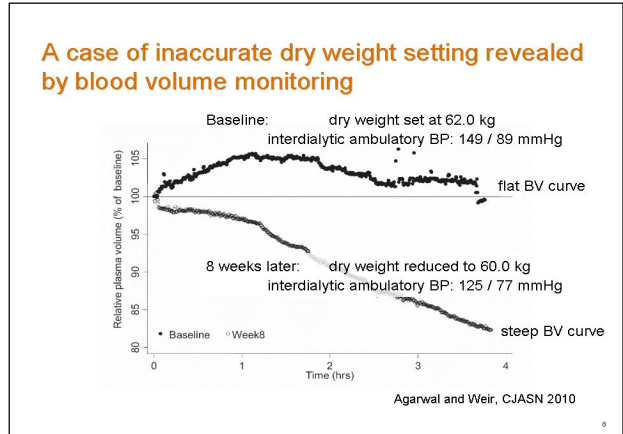
Ex) 투석 시작시 Hemoglobin (Hb) ⇒ 10
 투석 3시간 시점에서의 Hb ⇒ 11
 투석 3시간 시점에서의 BV% ⇒ (10/11-1) x 100 = -9%



Proposed guide to using Hemocontrol for dry body weight adjustment

		Intradialytic hypotension and/or other symptoms of hypovolemia (nausea, vomiting, headache)	
		No	Yes
BV/UFvol	less negative than -2 %/L	reduce dry weight by 0.3 kg per week until BV/UFvol falls between -2 and -4 %/L	evaluate for other factors as cause of hypotension
	between -2 and -4 %/L	no indication to change dry weight	evaluate for other factors as cause of hypotension
	more negative than -4 %/L	no indication to change dry weight	increase dry weight by 0.3 kg per week until BV/UFvol falls between -2 and -4 %/L and symptoms disappear

18



- Blood volume monitoring
- Ease of use and understanding
 - Allows for concomitant prevention of hypotension
 - May be useful to screen for an inappropriately high or low dry weight
 - Continuous plasma volume dependent on numerous factors other than hydration of the interstitial space
 - Measures relative volumes only
 - Interpatient variability

Definitions

Normovolemia

- Normal volumes of body water (ICW, ECW and TBW) in tissues and body fluid compartments adjusted for race, sex, age, and body composition distribution between lean and fat tissue
- Potentially an "absolute" definition

Dry weight

- The achieved post-dialysis weight (HD) or steady state weight (PD, CKD)
- The clinically-determined desirable target weight (post HD or steady state)

An absolute definition with a readily measured, acceptable accurate and clinically useful determination of normovolemic weight (and OH) is achievable at bed-side with BCM

Three phases of pre-dialysis MAP and post-dialysis weight

769 patients started on long slow HD in Tassin (1967-1994)

Phase	Duration	Key Features
Transition phase	~3mo	UF + strict low salt diet Hypotension and severe cramp Stop antihypertensive medication
Anabolic phase	3~12mo	Liberalize diet Follow dry weight increase
Stabilization	12~	Systemic and Incidental re-evaluation

Nephrol Dial Transplant (1996) 11 (Suppl 2): 16-19

BCM (Body Composition Monitor)

Normohydration weight

- The normohydration weight
 - normal hydration of body tissues in healthy controls with matched body composition (zero excess fluid)
 - Synonymous with normovolaemia or euvolaemia or the concept of normal extracellular volume.
- A possible target weight for a patient,
 - it does not necessarily mean that this weight can be achieved.
 - Comorbidity and the use of antihypertensive agents
 - factors that influence the vascular stability of a patient during treatment.

Can we do better?

- Simple, portable, repetitive
- Not invasive
- Relative inexpensive
- Moderate accurate
- High precision with serial measurement
- Differentiate ECV from ICW

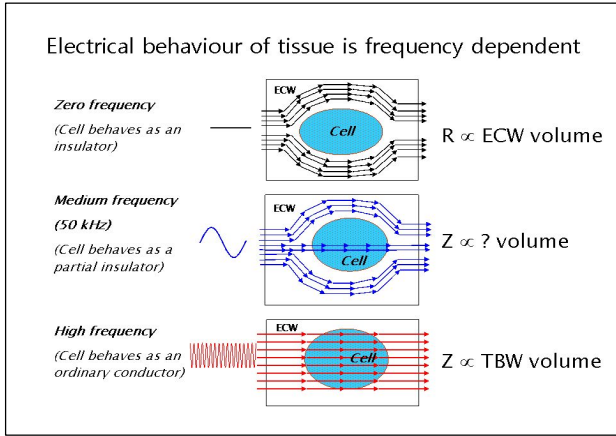
Electrical behaviour of body

The human body is a circuit of resistors and capacitors

Reactance (X): Cell membrane capacitor

Resistance (R): Electrolytic fluids

Impedance (Z): The integrated (net) impairment



BCM and normovolemia

- BIS estimates for ECW, ICW and TBW
- Known normal tissue hydration for **age, sex** and tissue E/I ratios from numerous reference data

Example:

- $\text{Lean}_{\text{NORMHYDR}} \text{ECW} + \text{Fat}_{\text{NORMHYDR}} \text{ECW} = \text{expected Total}_{\text{NORMHYDR}} \text{ECW}$
- $\text{Measured ECW} - \text{expected Total}_{\text{NORMHYDR}} \text{ECW} = \text{Overload or Overhydration (OH)}$
- $\text{Normovolemic weight} = \text{Measured weight} - \text{OH (kg)}$

Am J Clin Nutr 2007; 85: 80-89

Bioimpedance spectroscopy for management of fluid balance

	Gold standard method	Number	R ²	Mean ± SD
ECW	bromide	120 healthy subjects 32 HD patients	0.76	-0.1 ± 1.8 litres
	total body potassium		0.78	0.2 ± 2.3 litres
TBW	deuterium		0.88	-0.2 ± 2.3 litres
	tritium		0.94	-1.06 ± 1.9 litres
Fat	dual-energy X-ray absorptiometry	41 HD patients 19 liver patients 130 cancer patients 221 healthy subjects	0.82	-1.1 ± 4.2 kg
	air displacement plethysmography	25 HD patients 19 liver patients 141 healthy subjects	0.84	1.0 ± 4.1 kg
FFM	4-compartment modelling [33]	25 HD patients 141 healthy subjects	0.9	SEE = 3.4% -0.2 ± 3.5 kg
	dual-energy X-ray absorptiometry	22 HD patients 222 healthy subjects	0.89	-0.9 ± 3.7 kg
Fluid overload	clinical assessment	370 HD patients	n.a.	-0.23 ± 1.51 litres
	ultrafiltration volume	55 HD patients	R = 0.76	0.015 ± 0.8 litres

Accuracy : OH ± 1.1 Litre

Blood Purif 2009; 27: 75-80

BCM Targeted Dry Weight

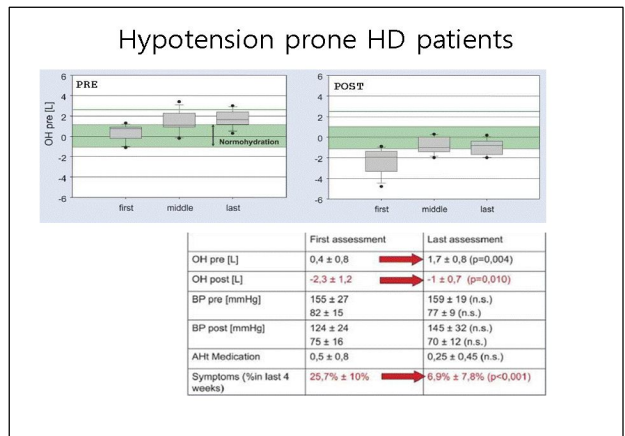
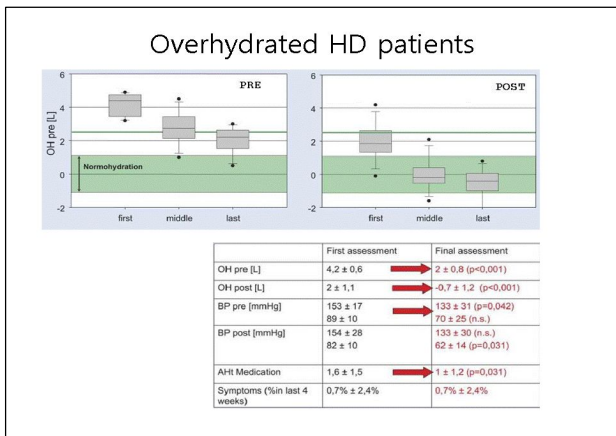
An alternative to the probing method and appropriate for hypervolemic and for hypotension prone patients

Guided optimisation of fluid status in HD patients

The aim of this interventional study was to guide the patient population of a complete dialysis centre towards normohydration over the course of **approximately one year**.

Fluid status was assessed frequently (at least monthly) in HD patients (**n=59**) with the BCM.

NDT 2009



Bioimpedance

- Hydric volumes correlates well with isotope dilution methods
- Ease of use, immediate results
- Reproducible/repeatable
- Measurement of interstitial space and ICF
- Immediate assessment of nutritional status
- Postdialysis measurements of ECF often underestimate UF
- Underestimates volume removed from trunk
- Accurate measurement of ICF confounded by temperature and ion effect
- Accurate measurement of ECF confounded by effect of recumbency

Table 4 Dry weight clinical assessment data

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(1) Case history	Excessive salt intake Dyspnea, headache	Diarrhea, vomiting, diuretics Postural dizziness, cramps
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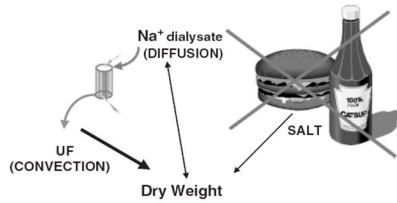
BP=blood pressure; ECV=extracellular volume.

Table 6 Summary of nonclinical ECV measurement methods

Method	ANP/BNP/cGMP	IVC Echo	Blood volume	Bioimpedance
ECV overload detection capacity	+	+	++	+++
ECV depletion detection capacity	0	+	±	+++
Plasma volume measuring capacity	+	++	+++	0
Interstitial space measuring capacity	0	0	0	++
Accuracy	±	±	±	±
Reproducibility	0	+	+	+++
Cost	±	++	++	++

ANP, atrial natriuretic peptide; BNP, brain natriuretic peptide; cGMP, cyclic guanosine monophosphate; ECV, extracellular volume; IVC=inferior vena cava. 0=nil; ± =very low; +=low; ++=medium; +++=high.

The 3 extracellular volume regulating methods in hemodialysis patients:



Reduced salt intake,
Reasonably low dialysate sodium concentration
Adequate ultrafiltration.