

An overview of dry weight estimation in dialysis patients

Masahide Furusho

Peking University Third Hospital

Outline of the presentation

- **Cardiovascular disease (CVD) in dialysis patients**
- **Poor long-term survival of this population**
- **The problem of overhydration (OH)**
- **Paradoxical change between blood pressure and hydration status**
- **Dry weight (DW) estimation**
- **The use of bioimpedance analysis (BIA)**

Fundamental issues in dialysis therapy

- Solute removal
- Volume control

CVD and ESRD

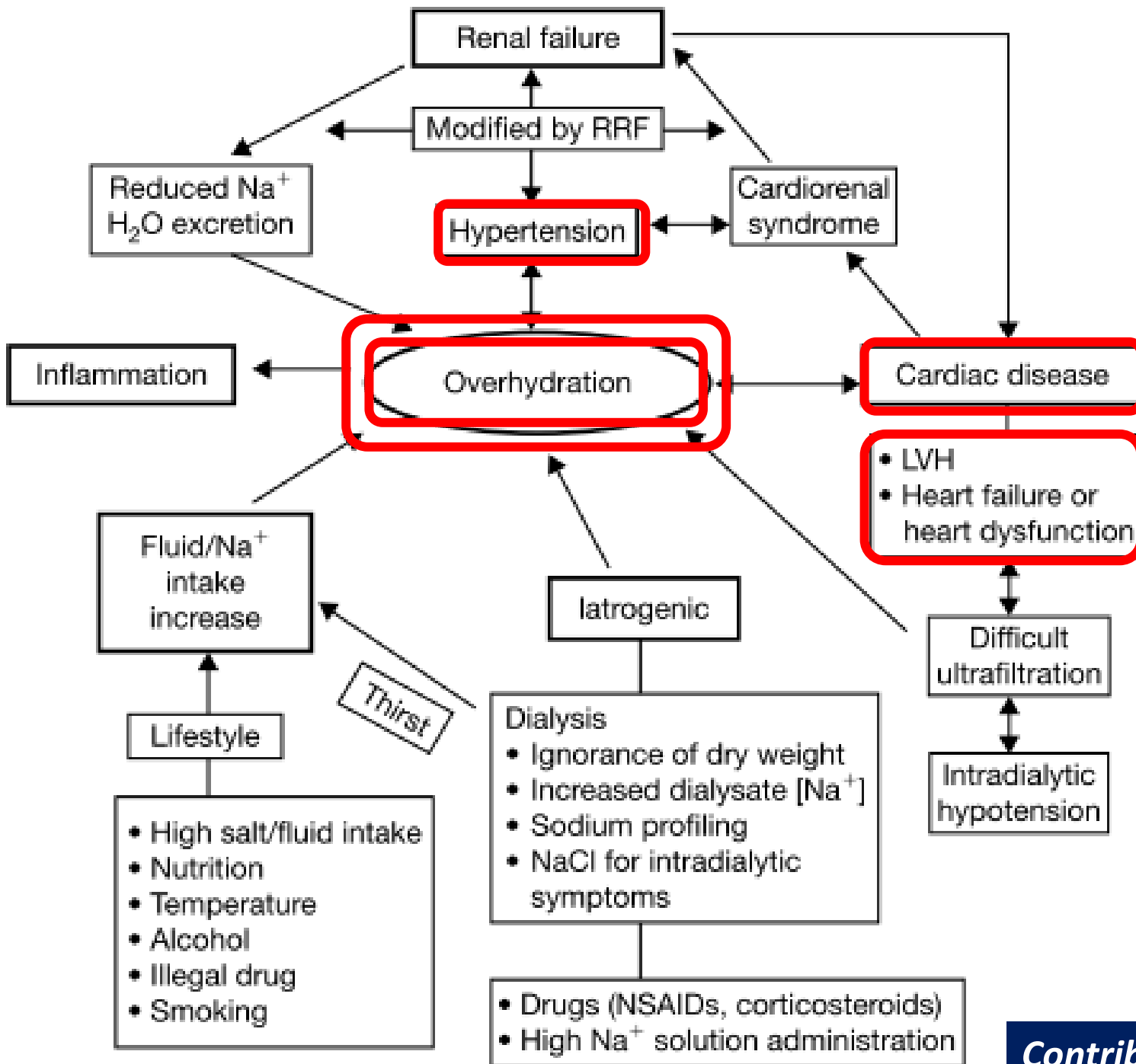
- CVD is the leading cause of mortality.
- Between 2005 and 2007, CVD was the primary cause for **almost 45% of all deaths** of dialysis patients in the U.S.

CVD and ESRD

- CVD mortality is **5 to 45 times** higher in dialysis patients who are 45 years old and older and **180 times** higher in dialysis patients between the ages of 20 to 45 compared to the general population.

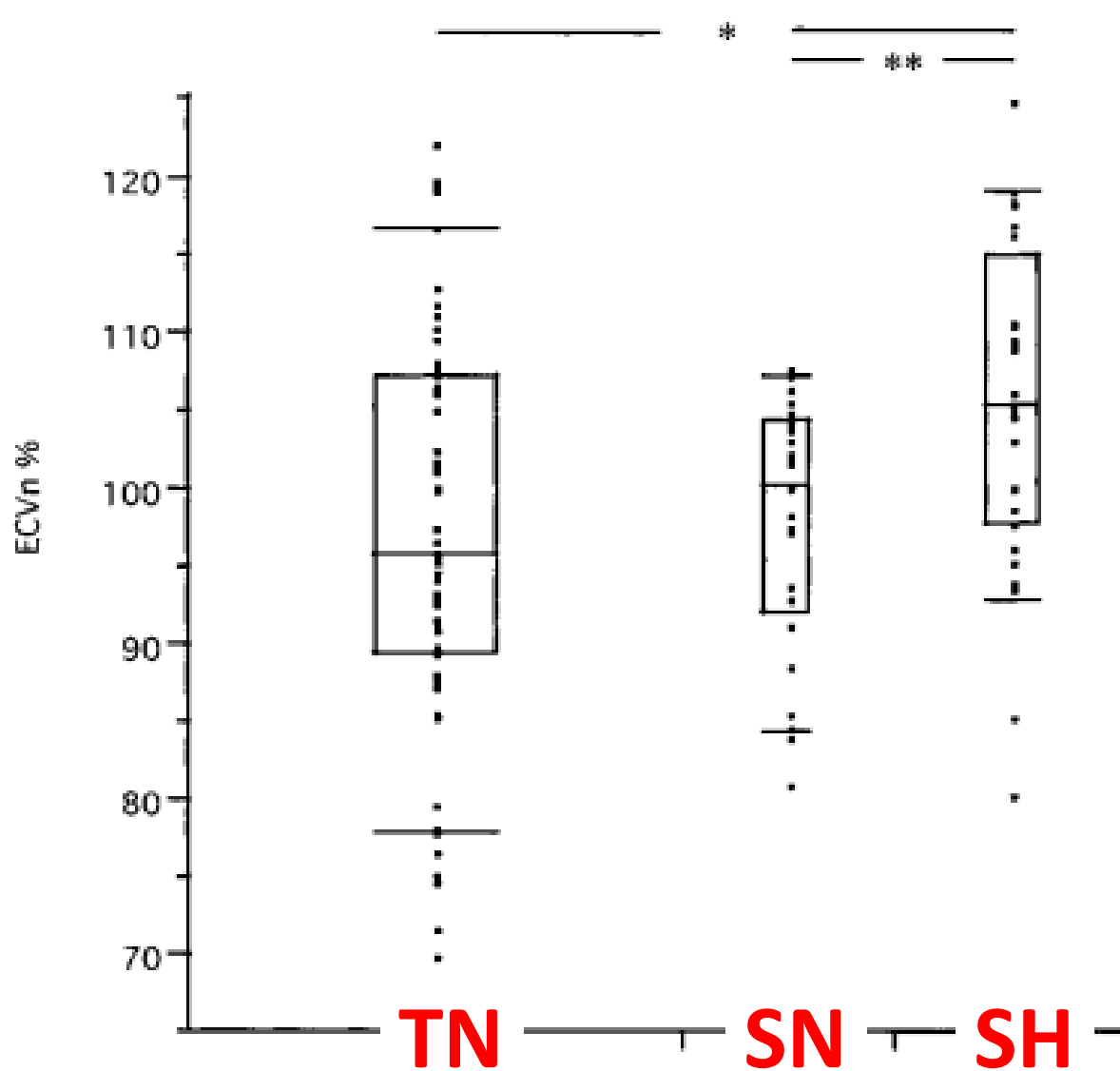
Poor long-term survival and ESRD

- Although mortality rates in ESRD patients have declined significantly over the past 20 years, the long-term survival remains poor.
- There are many risk factors for developing CVD in ESRD patients such as traditional risk factors and nontraditional risk factors.



Overhydration in dialysis patients

- Predicts the patient outcome
- Leads to high cardiac mortality
- Contribute to inflammation and malnutrition
- Increases blood pressure and arterial stiffness
- Decrease appetite and physical activity and quality of life



TN: (n=58)

Tassin normo-tensive

Long HD (8 hours)

SN: (n=25)

Swedish normo-tensive

Short HD (3-5 hours)

SH: (n=28)

Swedish hypertensive

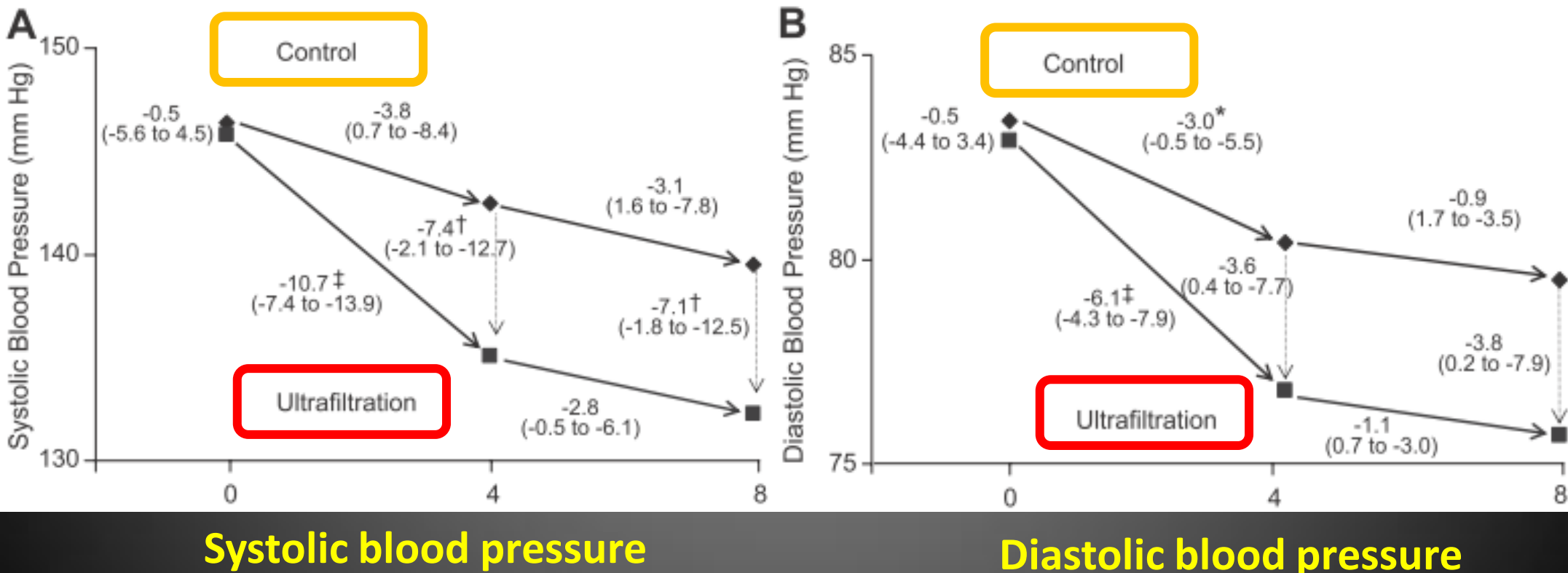
Short HD (3-5 hours)

Fig. 1. Normalized extracellular volume (ECVn) as a percentage of post-dialysis median ECV (as a percentage of post-dialysis body weight) in group TN ($n=58$), group SN ($n=25$) and group SH ($n=28$). The individual, median, and 10, 25, 75 and 90% quantile values are given. * $P=0.005$ vs groups TN; ** $P=0.0005$ vs groups

Dry-Weight Reduction in Hypertensive Hemodialysis Patients (DRIP)

A Randomized, Controlled Trial

Rajiv Agarwal, Pooneh Alborzi, Sangeetha Satyan, Robert P. Light



Strict Volume Control Normalizes Hypertension in Peritoneal Dialysis Patients

AKJD 2001;37:588-93

TABLE 1 -- Table 1. Results of 20 Patients Treated With Salt Restriction Alone

	Before Treatment	After Treatment	P
BW (kg)	64.1 ± 9.3	62.2 ± 8.5	<0.001
SBP (mm Hg)	152.4 ± 10.7	120.5 ± 17.5	<0.001
DBP (mm Hg)	91.5 ± 8.2	77.3 ± 11.3	<0.001
CTI (%)	47.1 ± 4.3	43.6 ± 4.6	<0.001
Hematocrit (%)	28.9 ± 2.8	30.3 ± 3.4	NS
Albumin (g/dL)	3.8 ± 0.4	4.0 ± 0.5	NS
UP (mL/d) (n = 9)	558.3 ± 511.7	211.1 ± 313.0	0.02

Abbreviations: BW, body weight; SBP, systolic BP; DBP, diastolic BP; UP, urine production.

TABLE 2 -- Table 2. Results of 17 Patients Treated With Salt Restriction and UF

	Before Treatment	After Treatment	P
BW (kg)	65.5 ± 13.0	61.7 ± 12.7	<0.001
SBP (mm Hg)	164.1 ± 20.2	118.8 ± 14.8	<0.001
DBP (mm Hg)	100.0 ± 10.6	78.5 ± 8.0	<0.001
CTI (%)	48.7 ± 6.3	42.2 ± 4.4	<0.001
Hematocrit (%)	30.7 ± 5.2	31.7 ± 4.0	NS
Albumin (g/dL)	3.6 ± 0.3	3.9 ± 0.4	NS
UP (mL/d) (n = 10)	705.0 ± 564.9	250.0 ± 305.5	0.01

Abbreviations: BW, body weight; SBP, systolic BP; DBP, diastolic BP; UP, urine production.

Dry weight in HD

- In 1967, Thomson initially defined dry weight as **the reduction of blood pressure to hypotensive levels during ultrafiltration.**
- In 1996, Charra suggested **'the post dialysis weight at which the patients can remain normotensive until the next dialysis without use of antihypertensive medications'**

Clin J Am Soc Nephrol 5: 1255–1260, 2010

Contrib Nephrol 161: 99–107, 2006

Contrib Nephrol 150: 104-110, 2006

Dry weight in PD

- Due to the steady state condition in PD, euvoolemia is more difficult to determine than in hemodialysis.

Contrib Nephrol 161: 99–107, 2006
Contrib Nephrol 150: 104-110, 2006

Assessment of fluid status

- **Clinical assessment (blood pressure, edema)**
- Tracer dilution techniques
- Relative blood volume (RBV) monitoring
- Chest X-ray (cardiothoracic index: CTI)
- Inferior vena cava diameter (IVCD)
- Biochemical markers (BNP, NT-pro BNP)
- Bioimpedance analysis (BIA)

Hydration status and edema formation

Clinical Characteristic	Overall	Edema	No Edema	P
Echocardiographic markers				
LVM/height ^{2.7} (g/m ^{2.7})	59.0 ± 16.6	69.9 ± 19.9	55.6 ± 14.0	<0.001
ejection fraction (%)	0.37 ± 0.08	0.38 ± 0.08	0.37 ± 0.08	0.51
IVC diameter (mm/m ²)	8.7 ± 3.7	8.5 ± 3.3	8.7 ± 3.8	0.8
IVC collapsibility index (%)	31.5 ± 17.9	27.2 ± 15.9	32.8 ± 18.3	0.13
right atrial pressure (mmHg)	6.1 ± 2.2	6.2 ± 3.1	6.1 ± 1.9	0.89
left atrial diameter (cm)	4.31 ± 0.67	4.35 ± 0.61	4.30 ± 0.69	0.75
pulmonary artery SBP (mmHg)	43.9 ± 9.4	47.2 ± 1.6	43.0 ± 9.6	0.04
elevated pulmonary artery SBP	9 (8)	2 (8)	7 (8)	0.96
Blood volume monitoring markers				
RBV index (slope %/h)	-2.35 ± 1.48	-2.27 ± 1.40	-2.37 ± 1.50	0.73
volume index (slope %/h per ml/kg RBV index)	-0.28 ± 0.18	-0.31 ± 0.23	-0.27 ± 0.16	0.18
UFR index (ml/kg per h)	8.4 ± 3.8	7.4 ± 3.1	8.7 ± 4.0	0.09

Hydration status and edema formation

Table 3. OR for edema in relation to obesity and left ventricular hypertrophy^a

BMI	LVM <68.8 g/m ^{2.7}			LVM ≥68.8 g/m ^{2.7}		
	OR	95% CI	P	OR	95% CI	P
Underweight or normal (<25 kg/m ²)	1			7.7	2.3 to 25.9	<0.001
Overweight (25.0 to 29.9 kg/m ²)	5.7	1.0 to 31.8	0.049	43.5	3.9 to 479.8	<0.01
Obese (>30 kg/m ²)	44.8	9.0 to 223.0	<0.001	344.8	33.8 to 3515.0	<0.001

^aOdds ratios (OR) and 95% confidence intervals (CI) associated with BMI and left ventricular hypertrophy adjusted for age. Hosmer-Lemeshow χ^2 1.50 ($P = 0.99$).

Table 4. OR for edema in relation to obesity and systolic hypertension^a

BMI	Home SBP <156 mmHg			Home SBP ≥156 mmHg		
	OR	95% CI	P	OR	95% CI	P
Underweight or normal (<25 kg/m ²)	1			5.3	1.3 to 21.8	0.02
Overweight (25.0 to 29.9 kg/m ²)	2.8	0.6 to 13.5	0.21	14.7	1.8 to 119.3	0.012
Obese (>30 kg/m ²)	41.2	8.9 to 190.5	<0.001	217.3	20.2 to 2234.6	<0.001

^aOR (95% CI) associated with BMI and systolic hypertension assessed by home BP monitoring adjusted for age and diastolic BP. Hosmer-Lemeshow χ^2 6.64 ($P = 0.58$).

FACTORS CONTRIBUTING TO FORMATION OF EDEMA IN VOLUME OVERLOADED CONTINUOUS AMBULATORY PERITONEAL DIALYSIS PATIENTS

Wen Tang,¹ Tian Xue,² Xin-Hong Lu,¹ Ya-Jun Luo,¹ and Tao Wang¹

*Division of Nephrology,¹ Peking University Third Hospital, Beijing;
Yijishan Hospital,² Wannan Medical College, Wuhu, China*

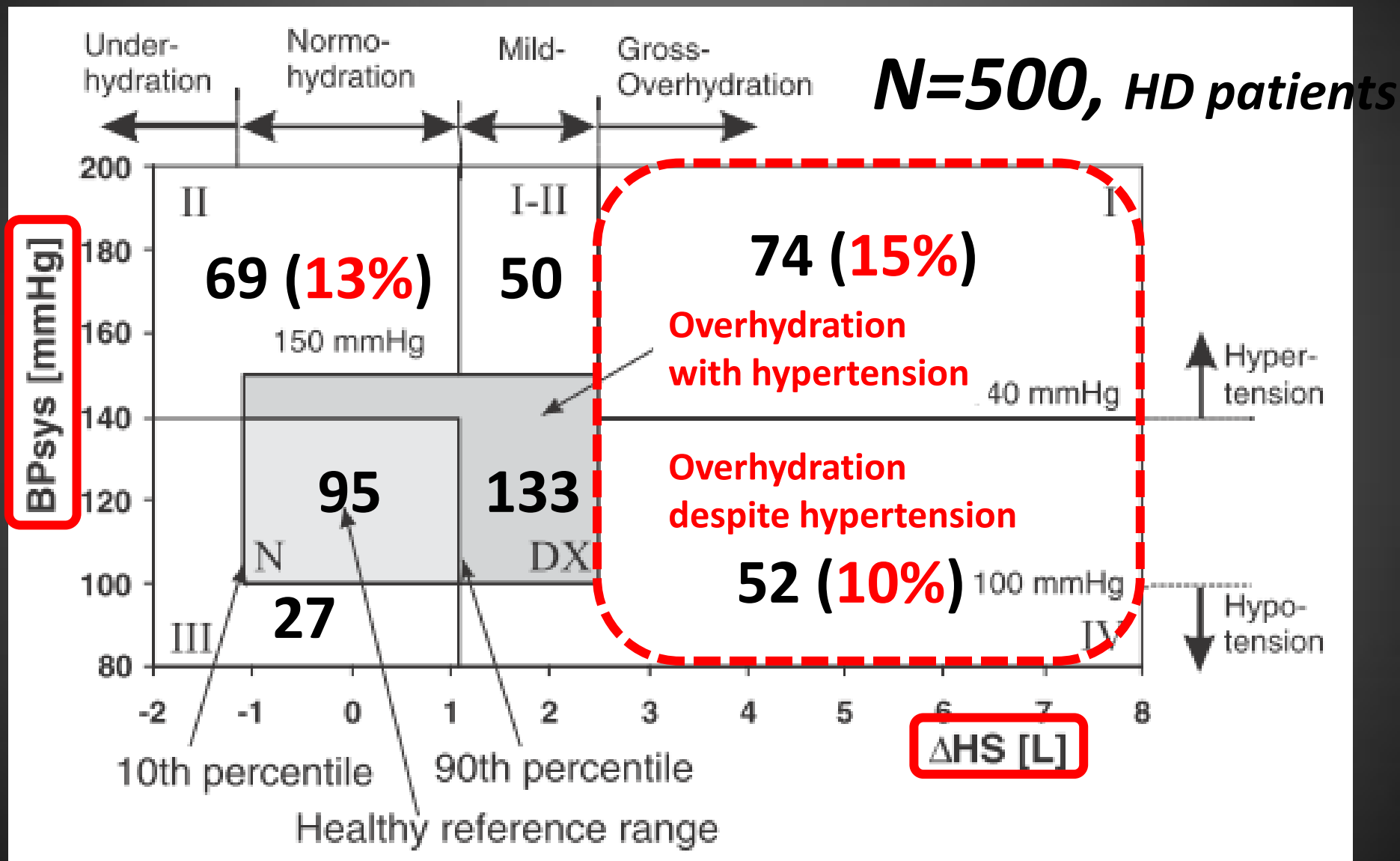
BMI	0.124	0.23
Malnutrition ^a	0.023	0.83
SBP	0.091	0.38
DBP	-0.032	0.76
sNa	-0.15	0.16
sALB	-0.18	0.055
tKt/V	0.058	0.59
tCcr	-0.034	0.74
Dialysis dose	0.07	0.53
Total fluid removal	0.188	0.074
GFR	-0.001	0.99
FMD (/%)	-0.33	0.001
Overhydration (/kg)	0.341	<0.001
Overhydration/TBW (/%)	0.401	<0.001
Use of CCB (yes=1, no=0)	0.14	NS

Not only overhydration and hypoalbuminemia but also endothelial dysfunction are independently correlated to edema formation in PD patients.

FMD (Flow Mediated Dilatation)

*Perit Dial Int 2011; 31:160-167*¹⁷

Hydration status and Blood pressure



FLUID STATUS, BLOOD PRESSURE, AND CARDIOVASCULAR ABNORMALITIES IN PATIENTS ON PERITONEAL DIALYSIS

Constantijn J.A.M. Konings, Jeroen P. Kooman, Marc Schonck,¹ Ruben Dammers,² Emiel Cheriex,³
Andrea P. Palmans Meulemans,³ Arnold P.G. Hoeks,² Bernardus van Kreel,⁴
Ulrich Gladziwa,⁵ Frank M. van der Sande, and Karel M.L. Leunissen

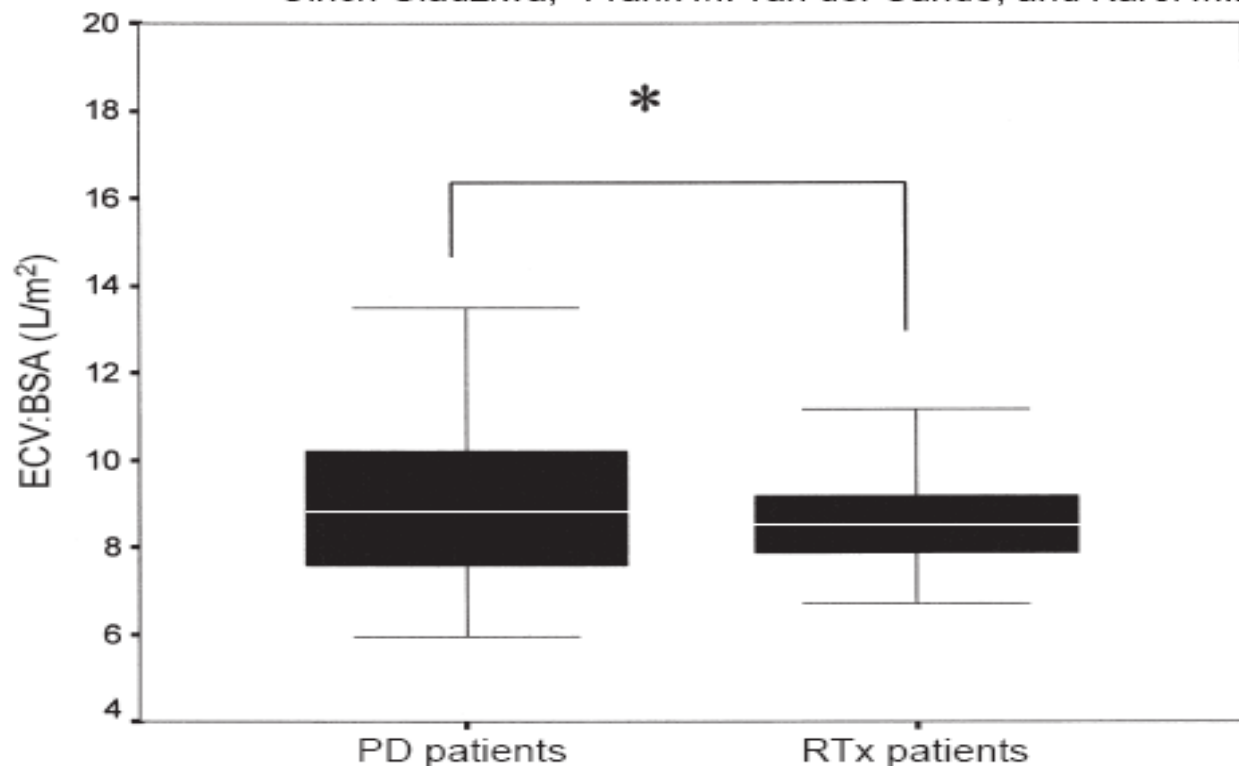


Figure 1 – Difference in fluid status between peritoneal dialysis (PD) patients and renal transplant patients (RTx). ECV:BSA = extracellular volume, determined by NaBr dilution, corrected for body surface area. * $p < 0.05$.

15 of the 41 PD patients (36.6%) were overhydrated, without hypertension and other clinical signs of volume overload.

Why Is There Significant Overlap in Volume Status between Hypertensive and Normotensive Patients on Dialysis?

Li-Tao Cheng^a Jun-Ping Tian^{a,b} Li-Jun Tang^{a,c} Hui-Min Chen^{a,d} Yue Gu^a
 Feng-He Du^b Tao Wang^a

Am J Nephrol 2008;28:508–516

Table 4. Comparison of hemodynamic parameters and LVMI among the four groups classified by 24-hour ABPM values

	Normotension Normohydration	Normotension Overhydration	Hypertension Normohydration	Hypertension Overhydration
SI, ml/m ²	37.4 ± 7.0	43.0 ± 12.6	43.7 ± 12.9	46.2 ± 9.88 ⁺
CI, l/m ²	2.6 ± 0.5	2.9 ± 0.5	2.9 ± 0.8	3.1 ± 0.9
TPRI, dyn · s · cm ⁻³	1,410 ± 306	944 ± 190 ⁺	1,329 ± 562**	1,161 ± 380
HR, beats/min	74 ± 10	73 ± 8	78 ± 9	71 ± 15
LVMI, g/m ²	109.2 ± 26.4	120.3 ± 27.4	130.7 ± 47.4	140.9 ± 43.6 ⁺

For explanation of the abbreviations, see text.

⁺ p < 0.05, comparison with CHT-NV group; ** p < 0.01, comparison with CHT-HV group.

The total peripheral resistance in the high volume status group were significantly lower than that of the normal volume status group. Therese result indicated that high volume status lead to decrease in total peripheral resistance.

The problem of clinical assessment

- **Paradoxical change**
 - autonomic nerve insufficiency
(parasympathetic activity ↑)
 - endothelial dysfunction, arterial stiffness...
- **Edema formation** is influenced not only overhydration and hypoalbuminemia but also LVH, obesity, and endothelial dysfunction.

Assessment of fluid status

- Clinical assessment (blood pressure, edema)
- Tracer dilution techniques
- **Relative blood volume (RBV) monitoring**
- **Chest X-ray (cardiothoracic index: CTI)**
- **Inferior vena cava diameter (IVCD)**
- **Biochemical markers (BNP, NT-pro BNP, ANP)**
- **Bioimpedance analysis (BIA)**

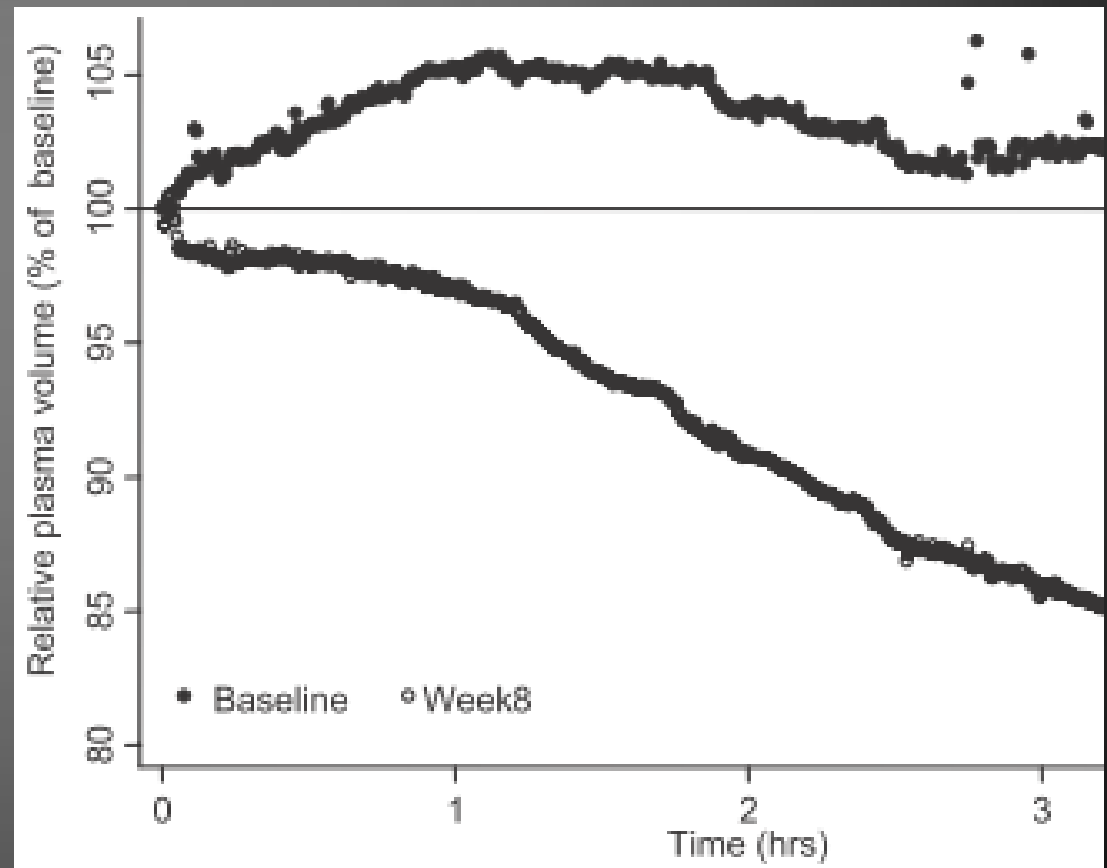
Nephrol Dial Transplant 2008, 23: 808–812

Seminars in Dialysis 2009, 22:9-12

Clin J Am Soc Nephrol 2010, 5:1255–1260

Relative blood volume (RBV) monitoring

- Assessed by measuring changes in hematocrit or protein during dialysis.
- The slope of the BV versus time curve is related to hydration state.
- There is not yet a standardized approach to estimate dry weight from intra-dialytic BV changes.



Chest X-ray (cardiothoracic index: CTI)

- Radiation
- Difficult to estimate minor increases in volume status
- Difficult to distinguish between normo- and under-hydration

Nephrol Dial Transplant 2008, 23: 808–812

Seminars in Dialysis 2009, 22:9-12

Clin J Am Soc Nephrol 2010, 5:1255–1260

Inferior vena cava diameter (IVCD)

- Related to right atrial pressure and plasma volume
- Influenced by cardiac disease (right-side)
- Inter operator error
- The timing of measurement is important because of the refill of plasma volume

Biochemical markers

(BNP, NT-pro-BNP, ANP)

- BNP and NT-pro BNP, released in response to left ventricular stress.
- These are useful serum cardiac biomarkers for prognostication and cardiovascular risk stratification.
- The role of detecting abnormalities of fluid status is under debate.
- Reflected not only by overhydration but also LVH and intrinsic cardiac disease.

Nephrol Dial Transplant 2008, 23: 808–812

Seminars in Dialysis 2009, 22:9-12

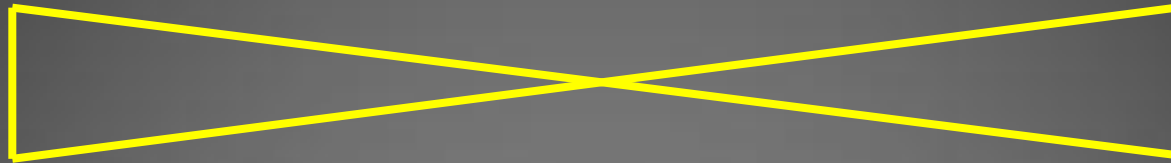
Clin J Am Soc Nephrol 2010, 5:1255–1260

Bioimpedance analysis (BIA)

Bioimpedance analysis (BIA)

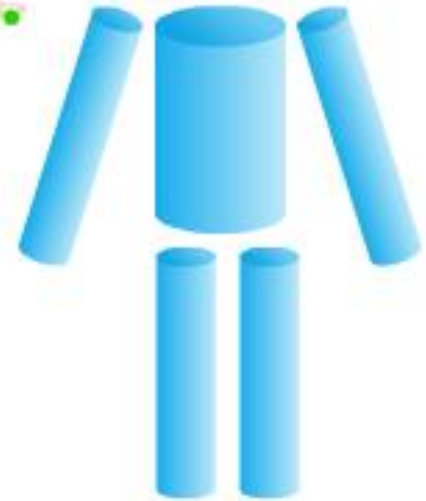
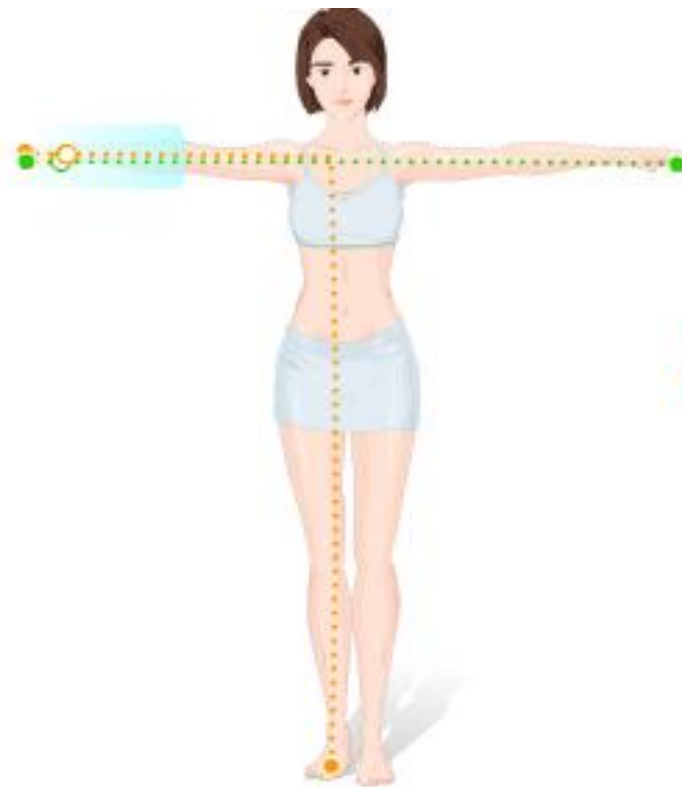
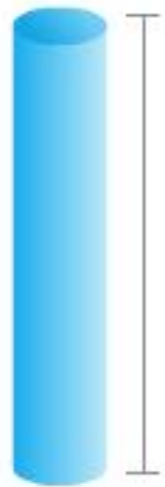
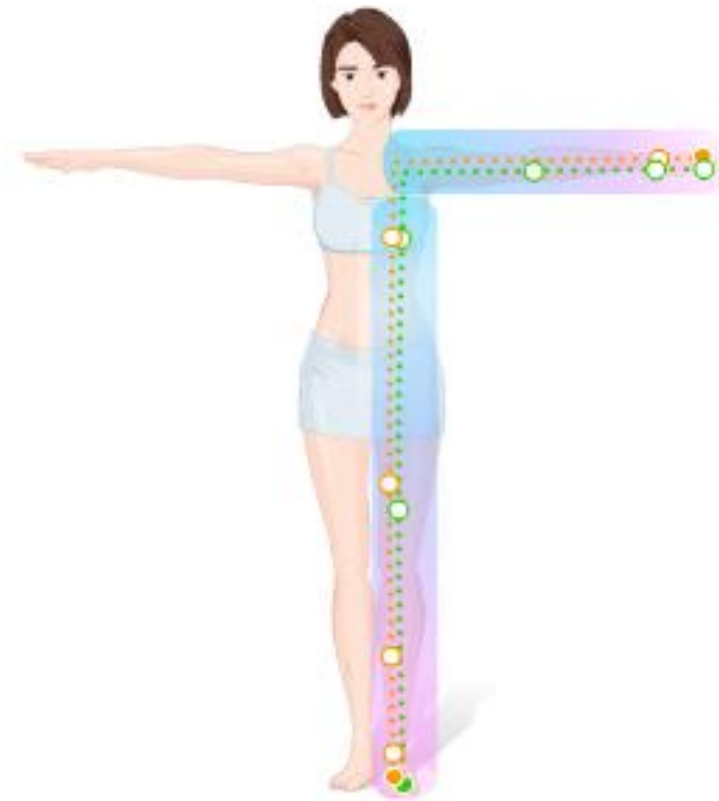
SF(single frequency)-BIA

MF(multi-frequency)-BIA



Whole body measurement

Segmental measurement



Principle of bioimpedance spectroscopy

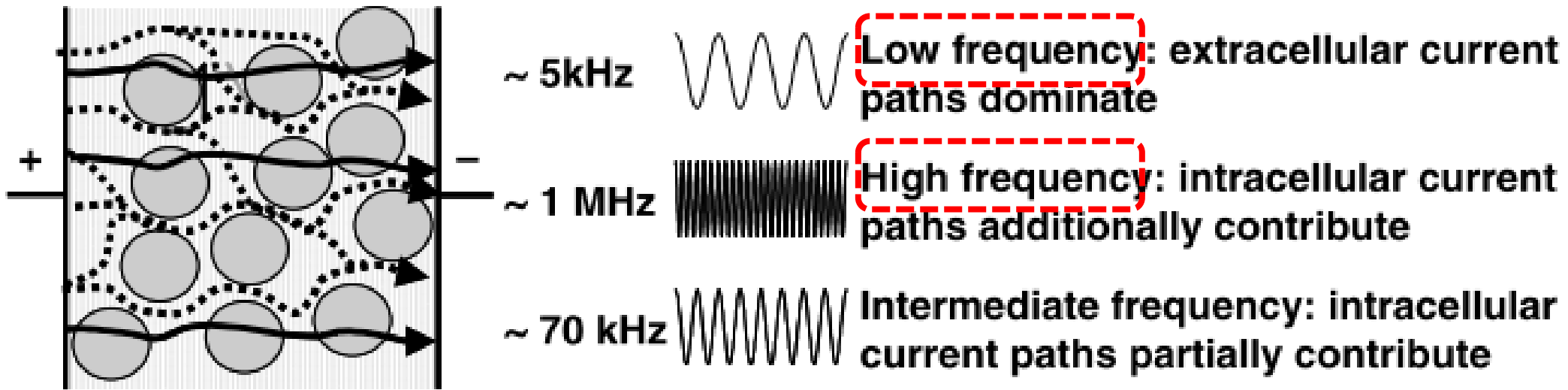
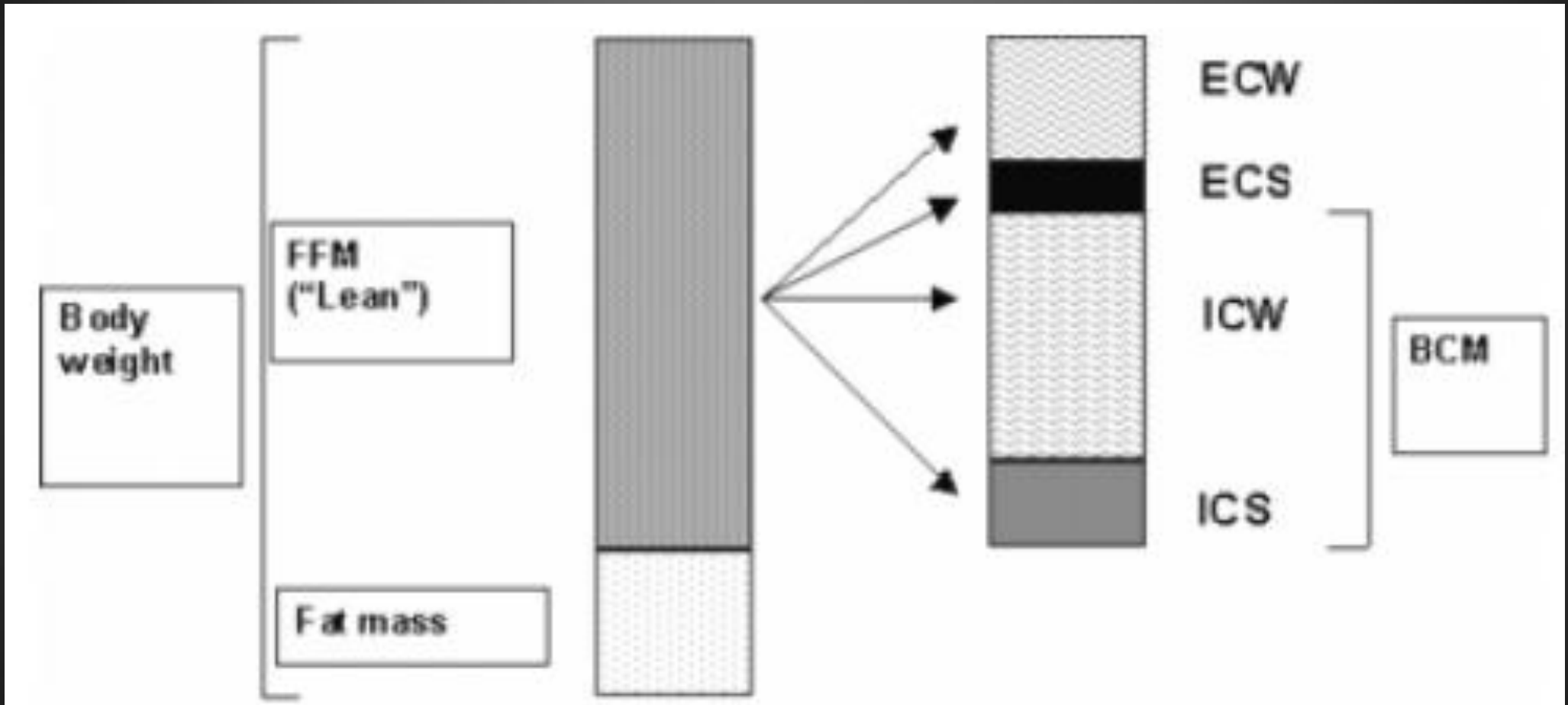


Figure 1 | Principle of bioimpedance spectroscopy for differentiation between intra- and extracellular fluid volumes.

2 compartment model



Bioimpedance analysis (BIA)

- Reproducibility
- Operator-independent method
- Management of volume status
- Assessment nutritional status
- Estimates fluid shift between compartment
 - FFM (ECW, ICW, ECS, ICS), Fat

Nephrol Dial Transplant 2008, 23: 808–812

Seminars in Dialysis 2009, 22:9-12

Clin J Am Soc Nephrol 2010, 5:1255–1260

How to normalize ECW ?

Weight? Height? TBW? etc...

Table 1. Hemodynamic parameters in patients classified according to clinical criteria

	'Normovolemic'	'Undetermined'	'Hypervolemic'	Healthy controls
n	12	44	34	20
Systolic BP, mm Hg	113 ± 15	129 ± 16*	149 ± 15*. [#]	
Diastolic BP, mm Hg	67 ± 10	77 ± 10 *	84 ± 11*. [#]	
ECW:height, liters/m	9.7 ± 1.3 [#]	11.7 ± 1.9*	11.8 ± 2.0*	12.2 ± 1.9*
ECW:weight, liters/kg	0.24 ± 0.02	0.26 ± 0.04	0.27 ± 0.05*	0.26 ± 0.03
ECW:TBW	0.52 ± 0.06 [#]	0.57 ± 0.05*	0.56 ± 0.05*	0.55 ± 0.02
Antihypertensives	0	1.6 ± 0.9 [0–4]*	2.6 ± 0.7*. [#]	
LVEDD, mm	47.4 ± 6.6	51.3 ± 5.0 [42–64]*	51.8 ± 5.2 [41–64]*	

ECW/height; sensitivity 86 %, specificity 80%

Blood Purif 2004;22:301–306

< Man: 10.96 liters/m, Female: 9.13 liters/m >

ECW/weight; sensitivity 76%,

influenced by overhydration, malnutrition, obesity, inflammation

ECW/TBW; sensitivity 45%, strongly influenced by age

BIA cannot distinguish intravascular and extravascular volume

1. If the excess fluid is considered **intravascular** and associated with hypertension or impaired cardiac function then attempts to normalize fluid status should be made.
2. If the fluid excess is mainly **extravascular**, as appears to be the case in the more hypoalbuminemic, frequently inflamed patients, then the trade off in achieving normovolemia and maintaining residual renal function.

BCM (Body Composition Monitor)



These reference methods include:

- Extracellular water – bromide dilution
- Intracellular water – total body potassium (TBK)
- Total Body Water – deuterium dilution
- Lean Tissue Mass – Dual Energy X-ray Absorptiometry (DEXA)
- Adipose Tissue Mass – 4-compartment modelling, DEXA, air displacement plethysmography and under water weighing
- Body Cell Mass – magnet resonance tomography, TBK
- Overhydration – by expert clinical assessment

Overhydration (Δ Hydration status)

- As normal ECW or TBW can be determined for a given weight and body composition, OH can be calculated from **the difference between the normal expected ECW and the measured ECW.**
- **The expected normal values of ECW or TBW that result with healthy kidney function.**
- The reference dates are **adjusted age and sex.**
- BCM can easily measure individual overhydration.

Conclusion

- **Overhydration is one of the most important risk factors for poor long-term survival and CVD.**
- **It is difficult to estimate volume status accurately in dialysis population.**
- **Clinical judgments such as BP and edema are not sufficient for the assessment of dry weight.**
- **We have to bear in mind the paradoxical change between blood pressure and volume status when we evaluate volume status.**
- **BIA is so far the most useful technique in assess and follow-up of hydration status clinically.**

Thank you