Opportunities to Harness Technology to Improve Blood Pressure and Volume Management in Maintenance Dialysis

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DISCLOSURES

- Speaker Honoraria from **Fresenius Medical Care**: 2018: Symposium on Intensive Care in Pörtschach, Austria - "Fluid " - (€ 900,00); 2017: Chairman, Scientific Symposium at ERA-EDTA in Madrid – "Orchestrating Electrolytes" - (€ 900,00); 2016: Meeting for Chinese Delegates at the ERA-EDTA in Vienna - Hemodiafiltration: "Clinical Aspects, Personal Opinion, Perspective in ESRD Care" - (€ 900,00)
- Speaker Honoraria from **Astellas Pharma**: 2016: Feldkirch, Austria; Salzburg, Austria, Innsbruck, Austria "Management of posttransplant diabetes" (€ 1800,00)
- Research grant from **Siemens Healthcare**: "Evaluation of the Siemens ADVIA Centaur® iPTH Assay in Hemodialysis Patients" (€ 35.475,00), "The longitudinal PTH study", clinical trials.gov: NCT03464149
- Research grant from **Boehringer Ingelheim**: "EMPagliflozin and RAs in Kidney Disease " (€ 321.935,00), clinicaltrials.gov: NCT03078101
- Research grant from **Astellas Pharma and Eli/Lilly**: "Early insulin therapy for prevention of posttransplant diabetes" (€ 154.170,00, € 33.000,00), "ITP-NODAT study", clinicaltrials.gov: NCT03507829
- Research grant from **Astellas Pharma**: "Sensor-Augmented Insulin Pump Therapy against Post-transplant Hyperglycemia: A Semi-Closed Loop System to Prevent New-Onset Diabetes after Renal Transplantation" (€ 42.825,00), "SAPT-NODAT study", clinicaltrials.gov: NCT01680185
- Research grant from **Astellas Pharma**: "Treat-to-target trial of basal insulin in post-transplant hyperglycemia (TIP): efficacy and safety of a novel protocol in renal transplant recipients receiving a tacrolimus-based immunosuppression" (€ 49.500,00), "TIP-study", clinicaltrials.gov: NCT00830297
- Research grant from **Nikkiso Co LTD**: "Response Options to Blood Volume Monitoring in Fluid Overloaded Hemodialysis Patients" (€ 20.000,00), "BVM-Reg study", clinicaltrials.gov: NCT01416753
- Competitive Academic Funding: Austrian Science Fund (**FWF**), **NIH/NIDDK**, Anniversary Fund of the **Austrian National Bank (OeNB), Else Kröner-Fresenius Foundation**

…Harness Technology to Improve Blood Pressure & Volume Management… The Link Between Blood Pressure & Volume: Historically Self-Evident?

Dry-Weight: A Concept Revisited in an Effort to Avoid Medication-Directed Approaches for Blood Pressure Control in Hemodialysis Patients

Thomson et al., *Arch Intern Med* 120: 153–167, 1967:

Reduction of blood pressure to hypotensive levels during ultrafiltration

Henderson, 1980:

Weight obtained at the conclusion of a regular dialysis treatment below which the patient more often than not will become symptomatic and go into shock.

Charra et al., *Nephrol Dial Transplant* 11[Suppl 2]: 16–19, 1996:

Body weight at the end of dialysis at which the patient can remain normotensive until the next dialysis despite the retention of saline and ideally without the use of antihypertensive medications

Raimann et al., 2008:

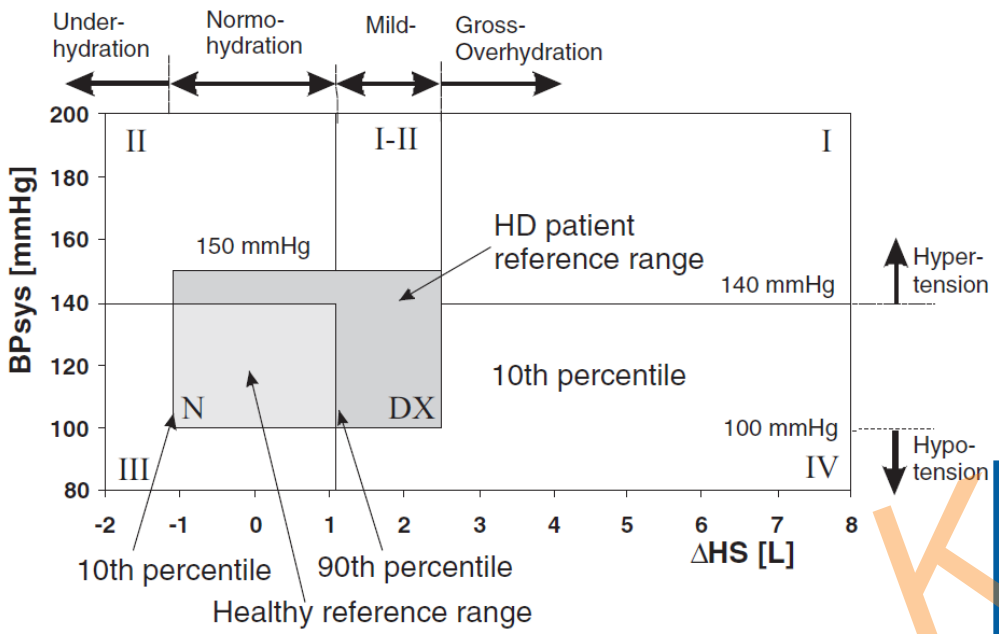
Defined by continuous calf bioimpedance analysis during dialysis. Dry-weight = flattening of the baseline/instantaneous impedance ratio curve for at least 20 minutes in the presence of ongoing ultrafiltration

Sinha & Agarwal, *Semin Dial* 22: 480–482, 2009:

A combination of subjective and objective measurements

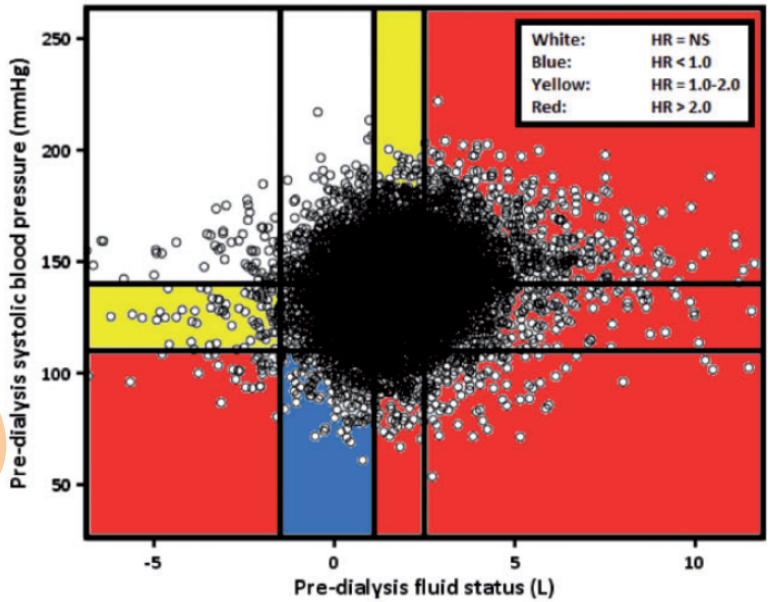
Agarwal R & Weir MR, *Clin J Am Soc Nephrol* 2010; 5: 1255-60

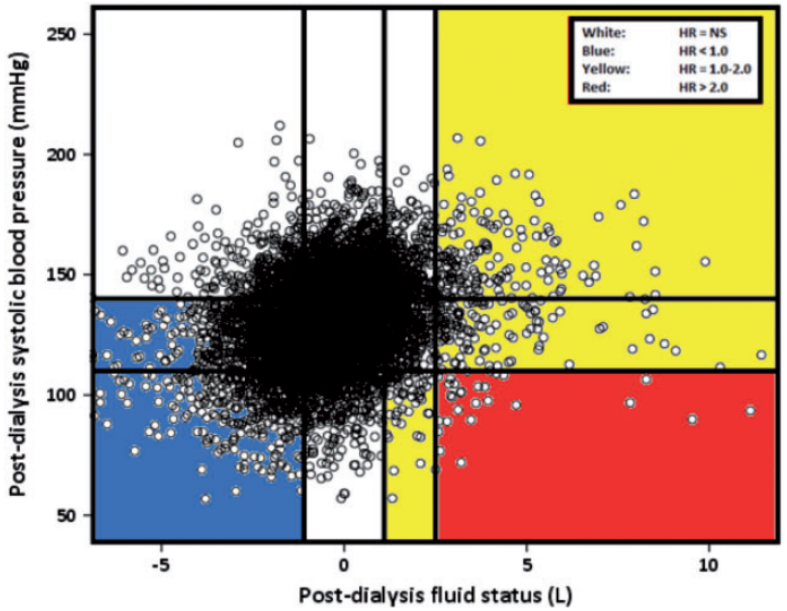
"Controversis Conference"… 1st Controversy May Be Blood Pressure:



I	
n	74
%	15

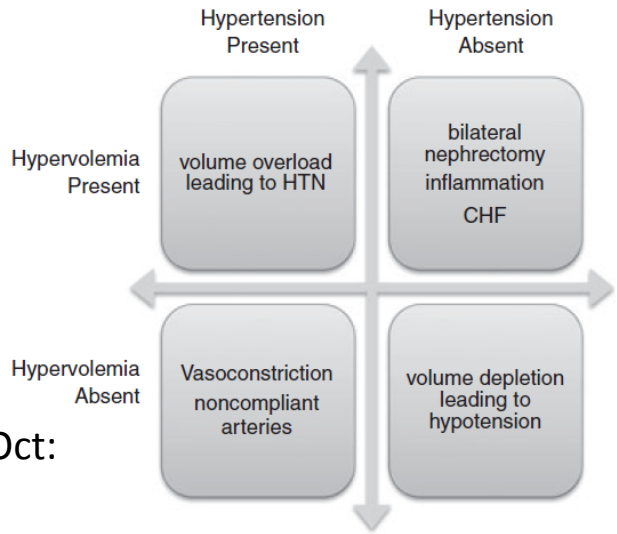
IV	
n	52
%	10





Wabel P et al., *Nephrol Dial Transplant* 2008; Sep;23(9): 2965-71

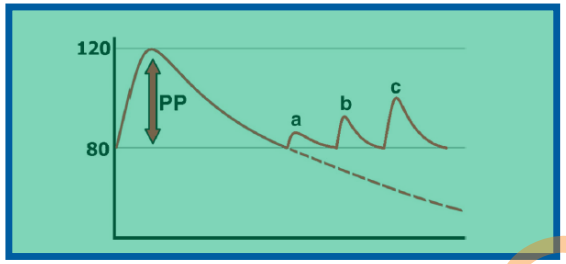
Sinha AD, Agarwal R, *Semin Dial* 2009; Sep-Oct: 22(5),480-2

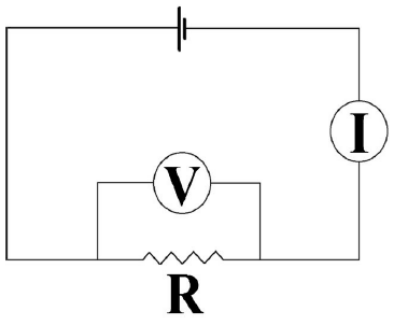


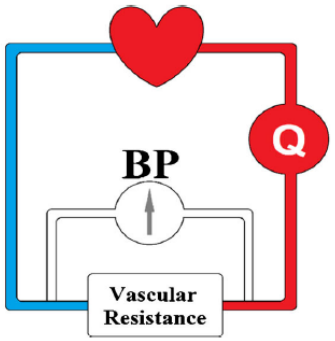
Dekker M et al., *Nephrol Dial Transplant* 2018; Nov 1;33(11):2027-2034

What Does Blood Pressure Depend On?

- **Q=cardiac output over 1 min**, a function of
  - stroke volume
    - Preload
    - Inotropy
    - Afterload
- **SVR=systemic vascular resistance**







V = I x R **BP = Q x SVR**

from which

R = V/I **SVR = BP/Q**

Smith BE, Madigan VM. *Curr Hypertens Rep*. 2018 Apr 10;20(4):29

JCI The Journal of Clinical Investigation

SODIUM AND POTASSIUM IN THE WALLS OF ARTERIOLES IN EXPERIMENTAL RENAL HYPERTENSION

Louis Tobian, … , Alice Tomboulian, Dorothy Ferreira

J Clin Invest. 1961;40(10):1922-1925. https://doi.org/10.1172/JCI104417.

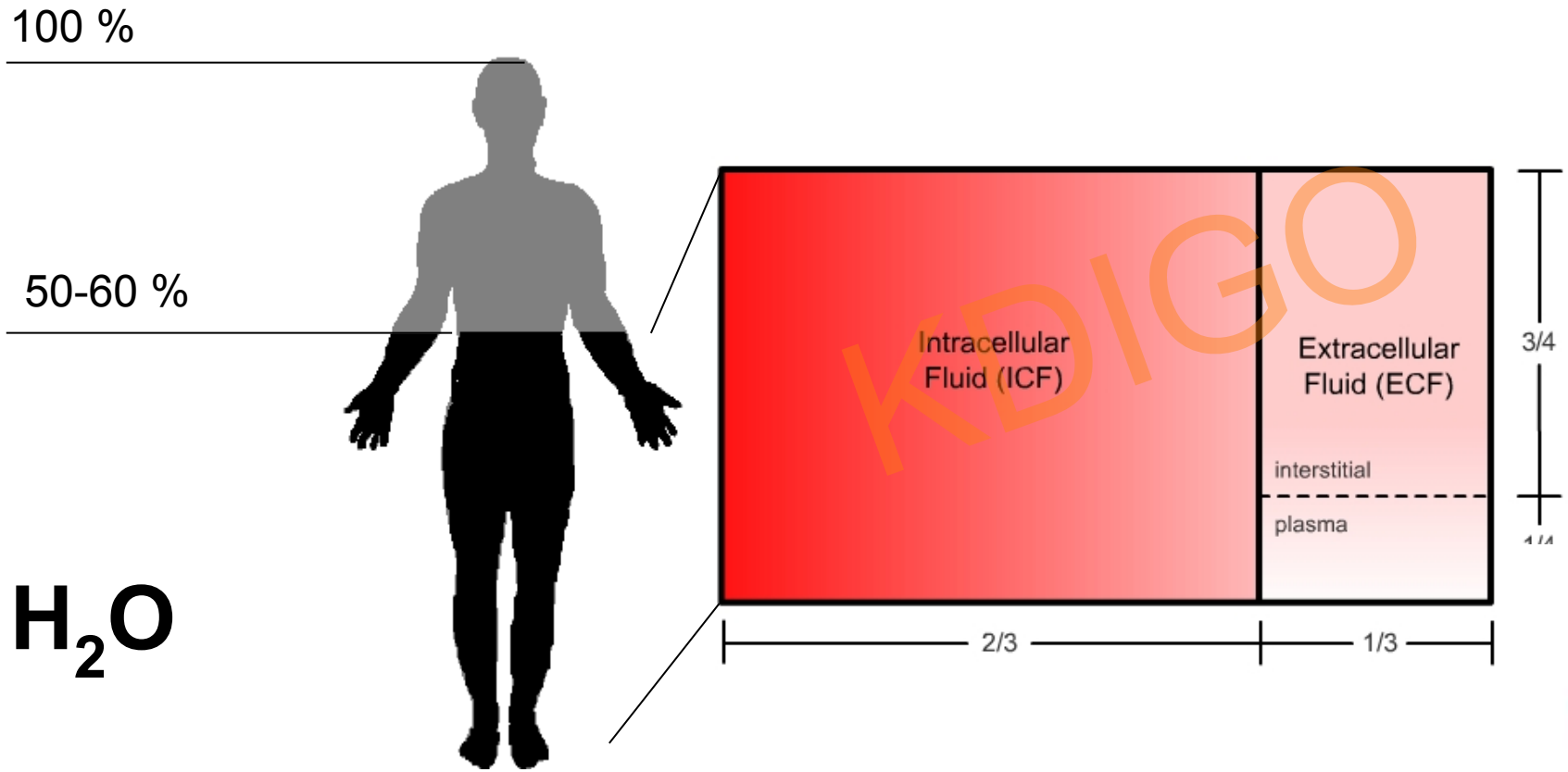
TABLE III

Average electrolyte levels in the arteriolar wall of various normotensive and hypertensive rats *

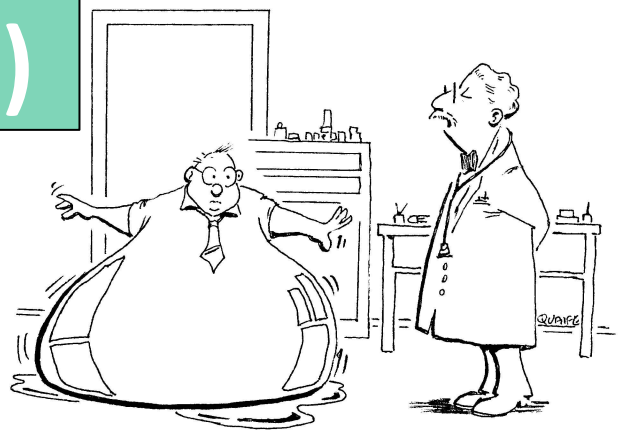
	25 Normal rats (A)	p Value of the difference between A and B	30 Rats with "cured" hypertension (B)	p Value of the difference between B and C	25 Rats with continuing hypertension (C)
Na (*mEq/100 g dry tissue*)	22.1 ± 0.4	0.03	23.5 ± 0.5	0.00006	27.3 ± 0.7
K (*mEq/100 g dry tissue*)	21.2 ± 0.3	>0.5	21.2 ± 0.3	0.3	21.7 ± 0.4
Cl (*mEq/100 g dry tissue*)	21.5 ± 0.8	0.5	22.3 ± 0.7	0.08	24.3 ± 0.9
Na + K (*mEq/100 g dry tissue*)	43.3 ± 0.6	0.14	44.6 ± 0.7	0.0004	49.0 ± 1.0
Arterial pressure† before clip removal (*mm Hg*)	126 (101–140)		197 (160–236)		202 (158–250)
Arterial pressure† one week after clip removal or sham operation (*mm Hg*)	125 (100–141)	0.02	132 (111–152)		197 (157–245)

* ± Indicates the standard error of the mean.
† Mean and range.

One Step Back: On Volume &Technologies (1) For Volume [Dry Weight] Assessment; (2) For Volume Management

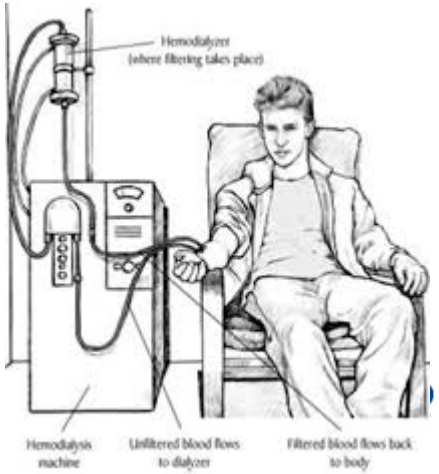


(1)



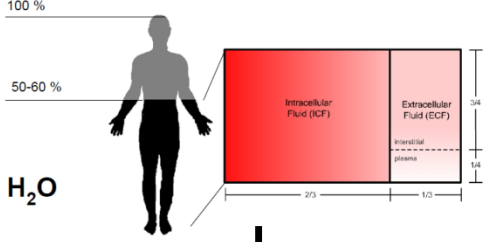
(2)

Your tests reveal that you are retaining fluids!



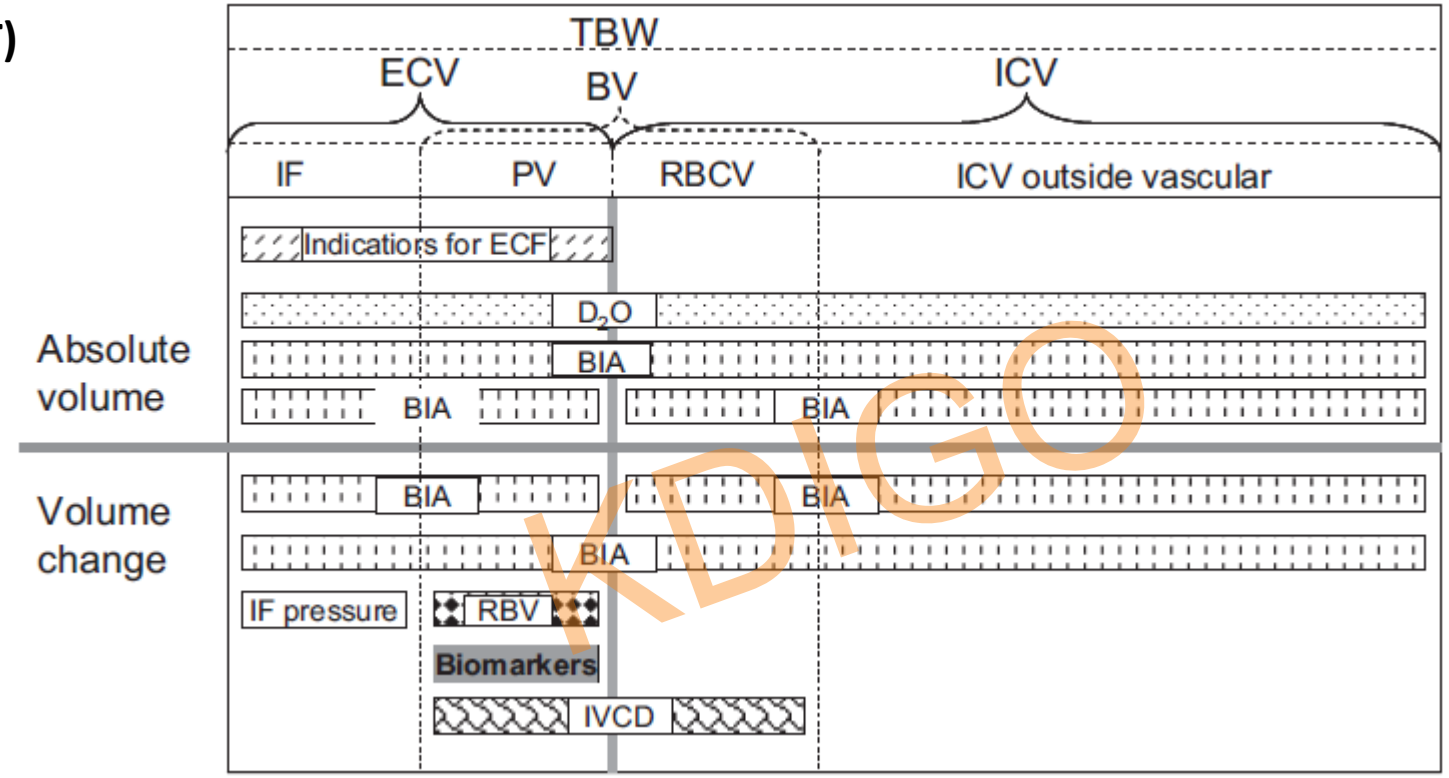
Terminology: **Water (Hydration)**
versus
Isotonic Fluid (Volume through 'salt' + water)

Fluid Volume Assessment



(DIRECT)

- Total Body Volume* (=TBV, =TBW)
- Intracellular Volume* (=ICV, =ICW)
- Extracellular Volume* (=ECV, =ECW)
- Total Blood Volume* (=TBV, =TBW)



Dou Y, et al., *Semin Dial*. 2012 Jul;25(4):377-87

(INDIRECT)

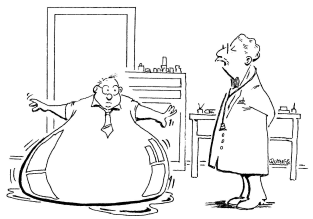
- Pedal Edema
- Chest X-ray
- Inferior Vena Cava Diameter
- Biochemical Markers
- Lung Comets
- (Diagnostic) Relative Blood Volume Monitoring
- Dual-energy X-ray absorptiometry (=DXA)
- Magnetic Resonance Imaging (MRI)
- Echocardiography
- Pulmonary Artery Pressure
- Pulse Pressure
- Stroke Volume Variation
- Leg Raising Test
- Blood Pressure

*Gold Standards:

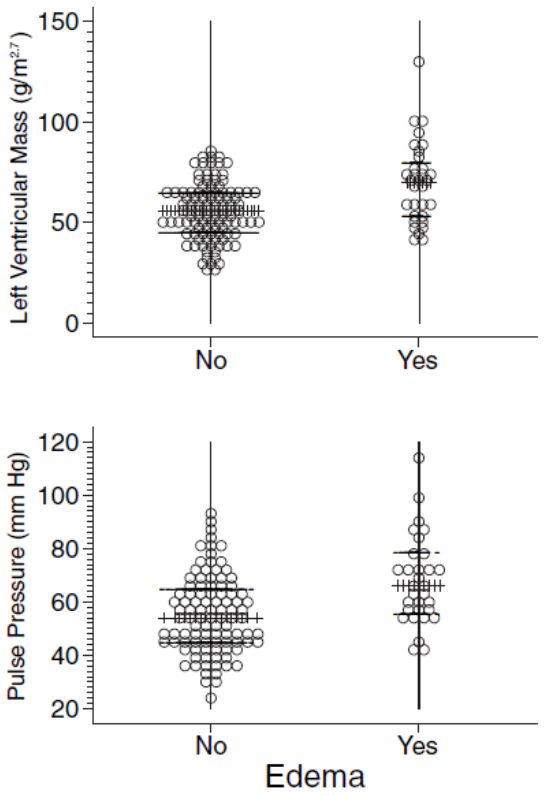
- Total Body Volume: Deuterium (D_2O) Dilution
- Intracellular Volume: ICV_{TBK} = Total Body Potassium (TBK)/152 [intracellular K = 152 mmol/L]
- Extracellular Volume: Sodium bromide (NaBr) Dilution
- Total Blood Volume: ^{131}I-labeled albumin + ^{51}Cr-labeled red cells → Indocyanine Green

Moissl U et al., *Physiol Meas* 2006 Sep;27(9):921-33

Fluid Volume Assessment



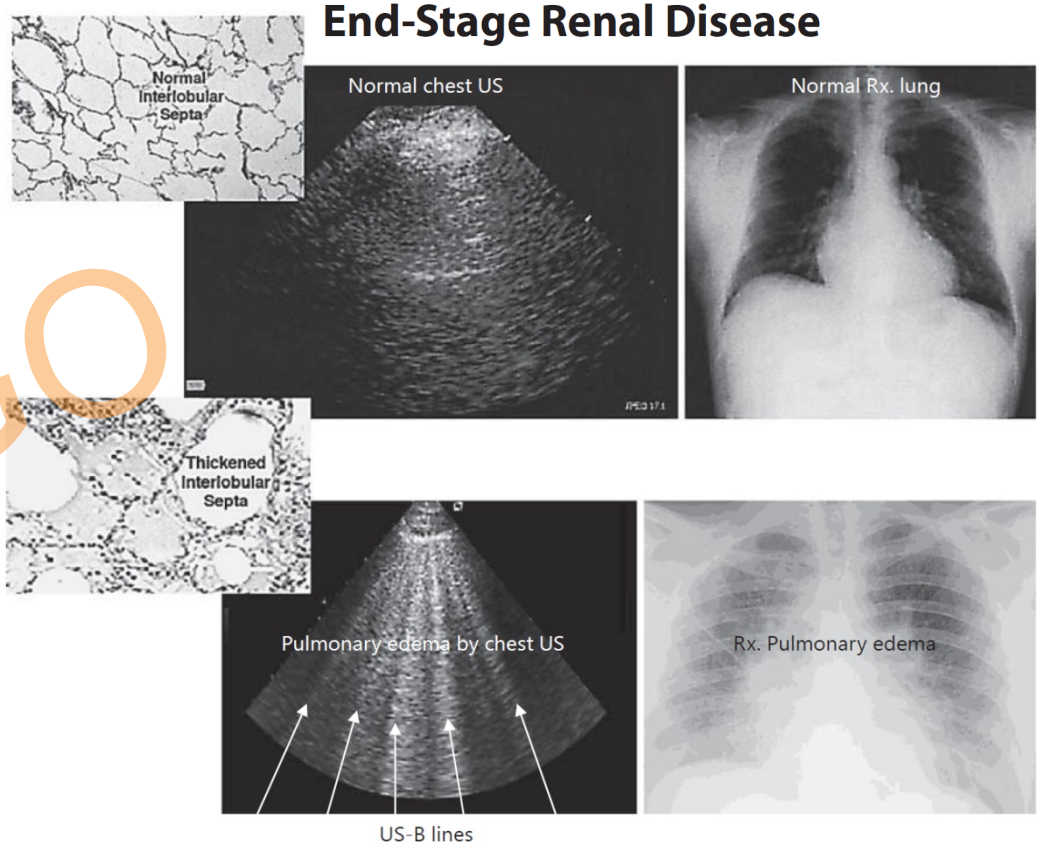
On the Importance of Pedal Edema in Hemodialysis Patients



- Pedal Edema
- Chest X-ray
- Inferior Vena Cava Diameter
- Lung Comets
- (Diagnostic) Relative Blood Volume Monitoring
- Echocardiography
- Pulse Pressure

...in 2 papers only

Lung Congestion as a Risk Factor in End-Stage Renal Disease



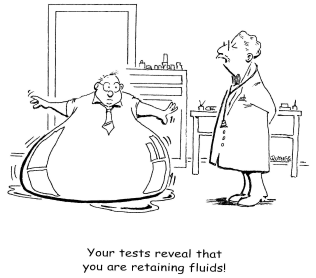
Inferior vena cava diameter, blood volume monitoring, plasma volume markers, and inflammation markers **were not determinants of edema.**

Agarwal R et al., *Clin J Am Soc Nephrol.* 2008 Jan;3(1):153-8

[…] "patients with very severe congestion had a 4.2-fold risk of death (**HR=4.20, 95% CI=2.45-7.23**) […] adjusted for NYHA class and other risk factors"

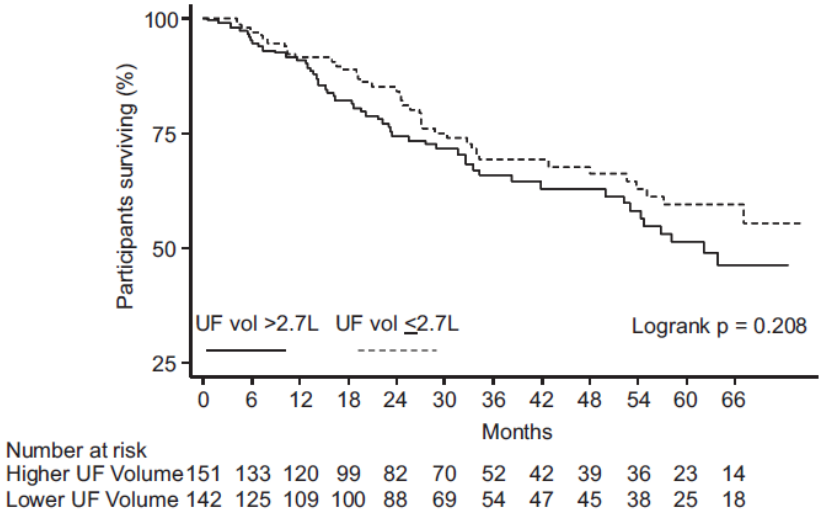
Zoccali C et al., *Blood Purif.* 2013;36(3-4):184-91
Zoccali C et al., *J Am Soc Nephrol.* 2013 Mar;24(4):639-46

Fluid Volume Assessment



- **(Diagnostic) Relative Blood Volume Monitoring**
  - **Prognostic Importance**

Agarwal R et al., *Hypertension.* 2010 Sep;56(3):512-7



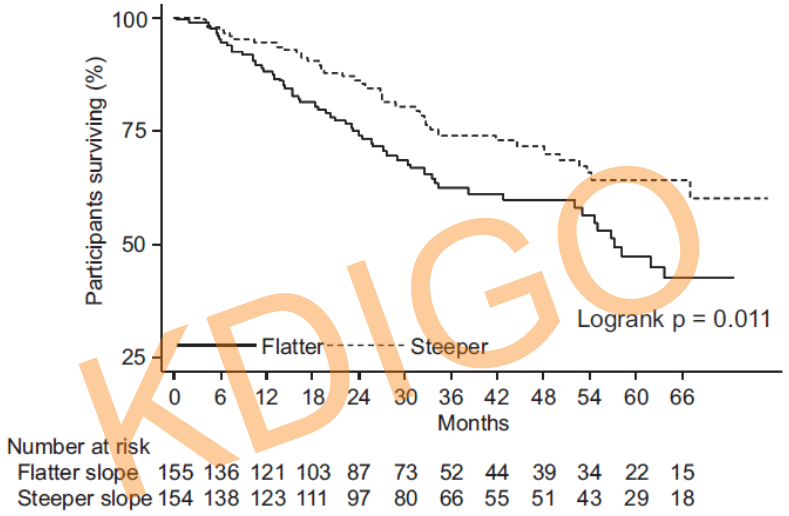


Table 2. Hazard Ratios for All-Cause Mortality by Median of UF Volume or RPV Slope

Parameter	HR	95% CI	*P*	Model Fit (χ^2)
UF volume	0.78	0.51 to 1.17	0.23	1.45
UF volume/postdialysis weight	0.79	0.52 to 1.19	0.25	1.3
UF rate/postdialysis weight	0.89	0.59 to 1.34	0.58	0.6
RPV slope	1.72	1.14 to 2.58	0.01	6.85

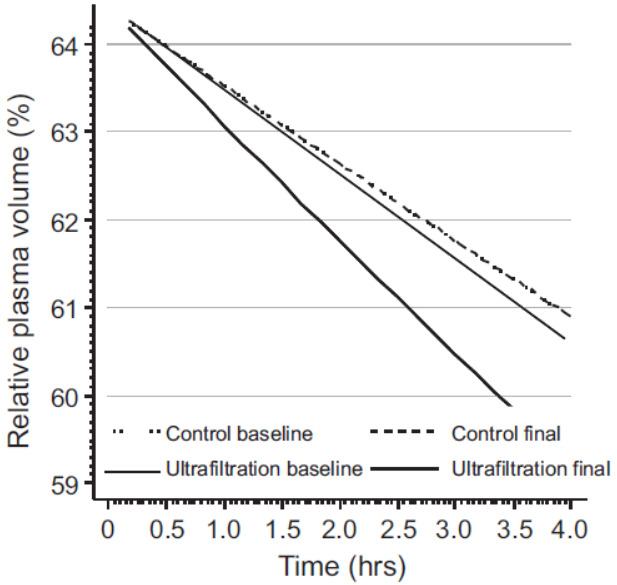
Hazard ratio (HR) is for the upper half compared with lower half. RPV slope compares the hazard ratio of flatter to steeper slope.

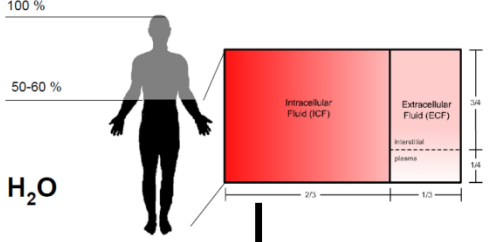
- **(Diagnostic) Relative Blood Volume Monitoring**
  - **Practical Relevance**

Relative Plasma Volume Monitoring During Hemodialysis Aids the Assessment of Dry Weight

Arjun D. Sinha, Robert P. Light and Rajiv Agarwal

Hypertension. 2010 Feb;55(2):305-11





Fluid Volume Assessment

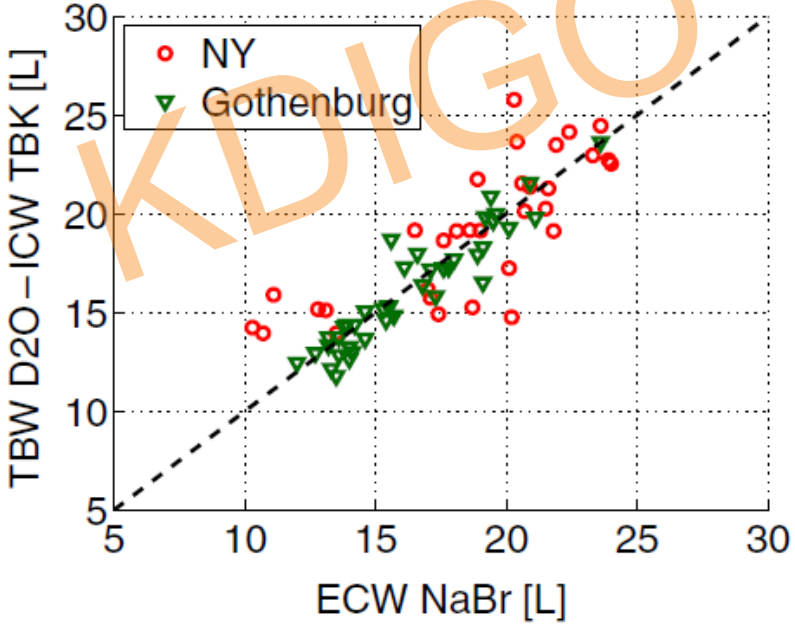
FROM HERE (TOTAL VOLUMES)

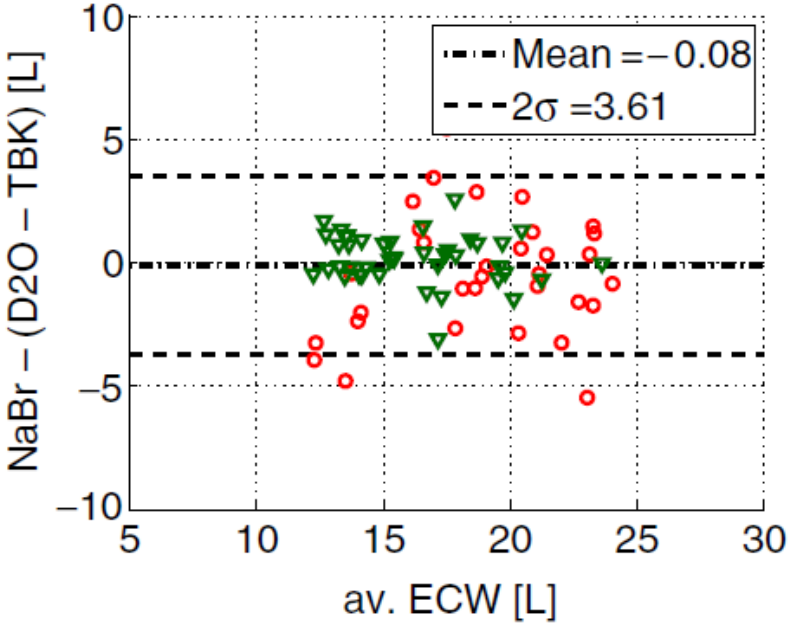
TO THERE (HOW MUCH IS TOO MUCH)

Body fluid volume determination via body composition spectroscopy in health and disease

***Gold Standards:**

- **Total Body Volume: Deuterium (D_2O) Dilution**
- **Intracellular Volume: ICV_{TBK} = Total Body Potassium (TBK)/152**
  [intracellular K = 152 mmol/L]
- **Extracellular Volume: Sodium bromide (NaBr) Dilution**



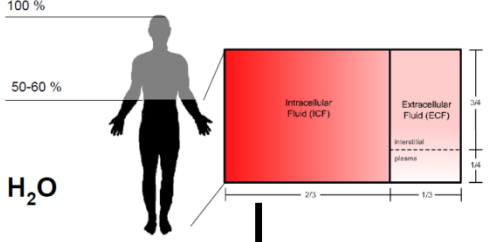


TBW D_2O = ECW NaBr + ICW TBK

ECW NaBr = TBW D_2O – ICW TBK

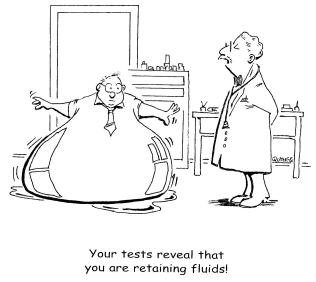
Moissl U et al., *Physiol Meas* 2006 Sep;27(9):921-33

FLUID VOLUME ASSESSMENT



FROM HERE
(TOTAL VOLUMES)

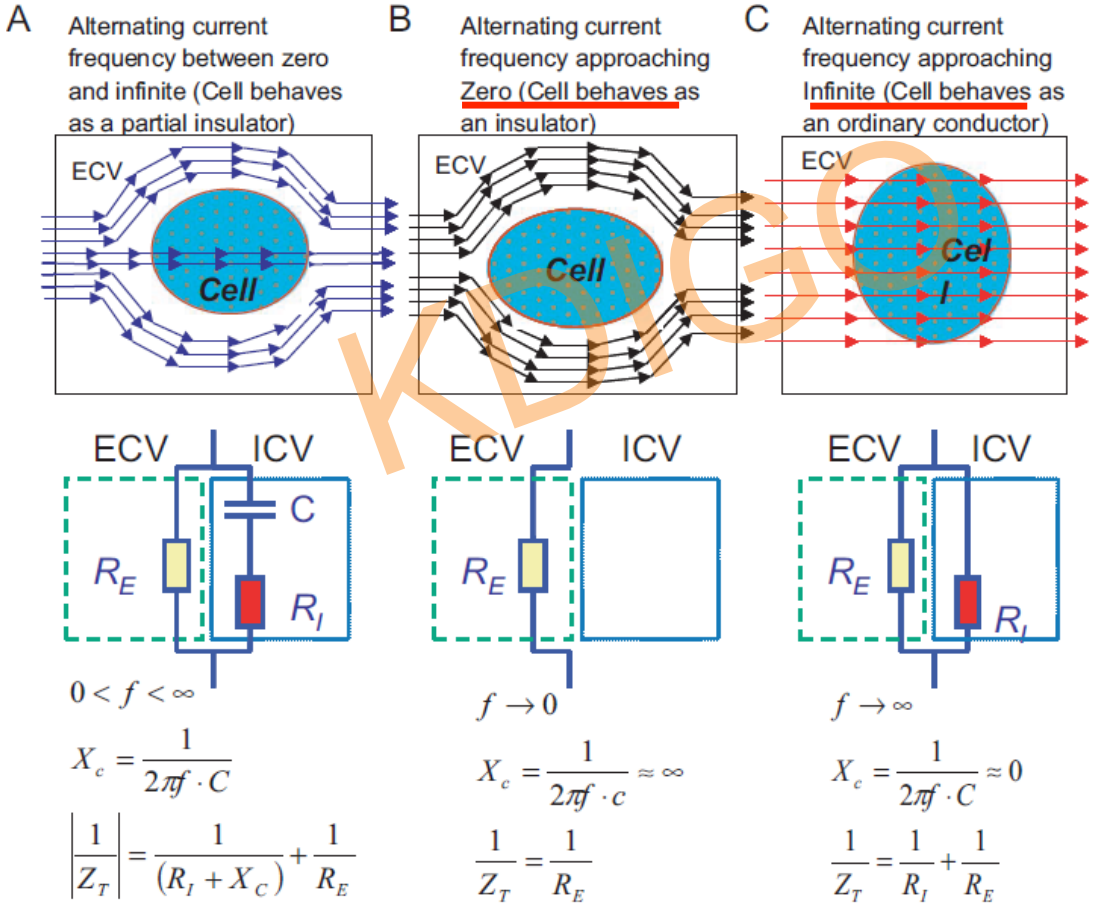
Assessment of Extracellular Fluid Volume and Fluid Status in Hemodialysis Patients: Current Status and Technical Advances



TO THERE
(HOW MUCH IS TOO MUCH)

Direct Current
→ Resistance

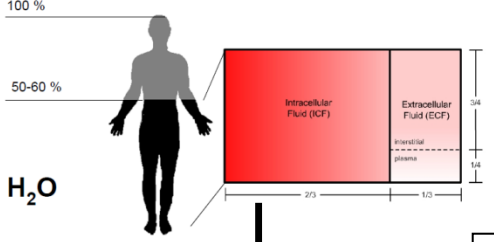
Alternating Curent
→ Resistance & Reactance



Cole Model
→ From 50 phase angles to Capacitance and
→ Resistance E
→ Resistance I

Hanai Model
→ From RE and RI to ECV und ICV

Dou Y et al., *Semin Dial* 2012 Jul;25(4):377-87

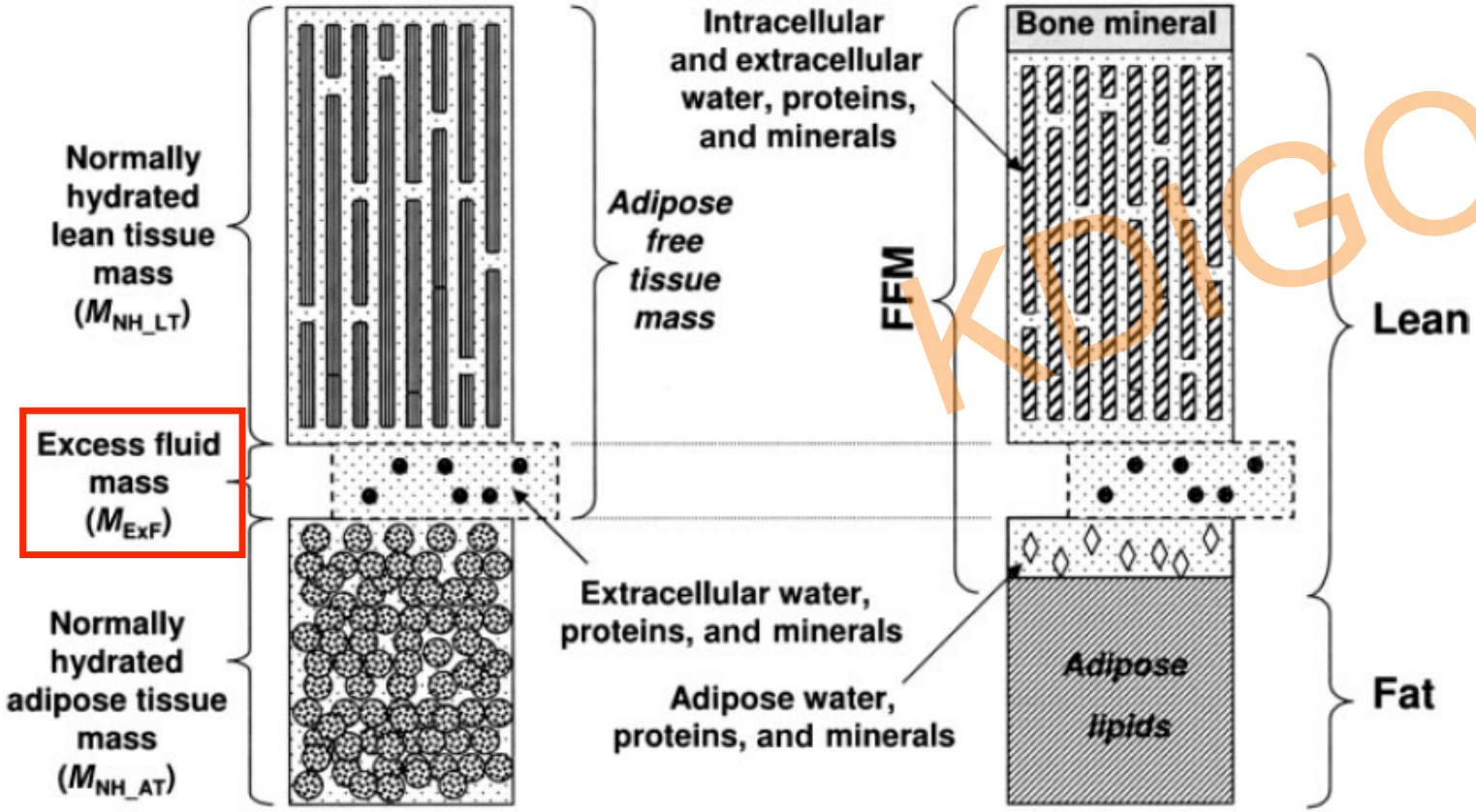


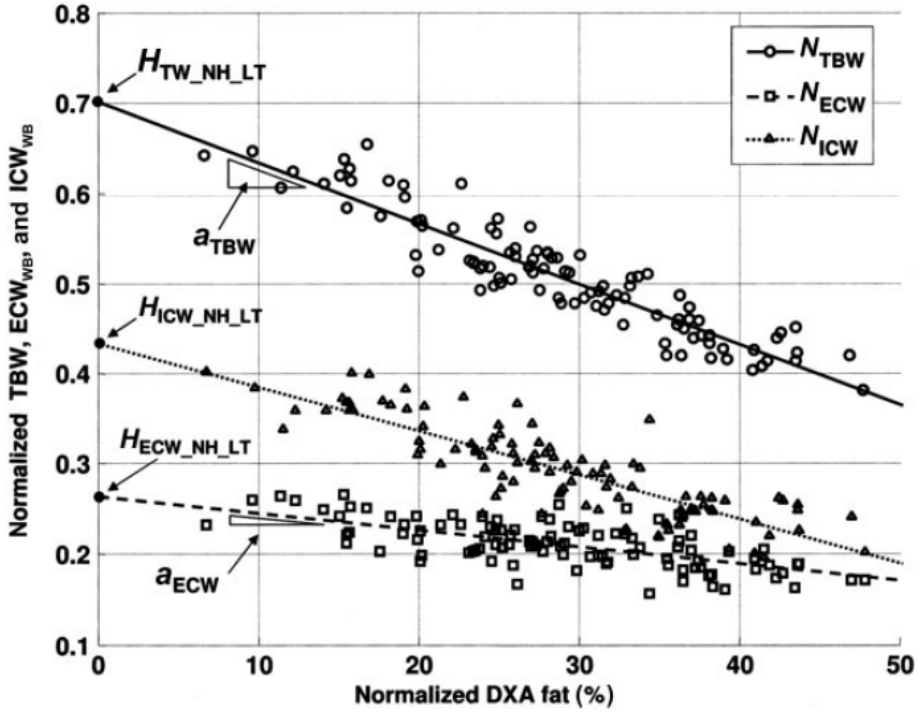
Fluid Volume Assessment

FROM HERE (TOTAL VOLUMES)

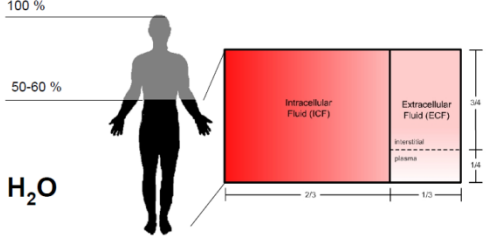
A whole-body model to distinguish excess fluid from the hydration of major body tissues[1–3]

TO THERE (HOW MUCH IS TOO MUCH)





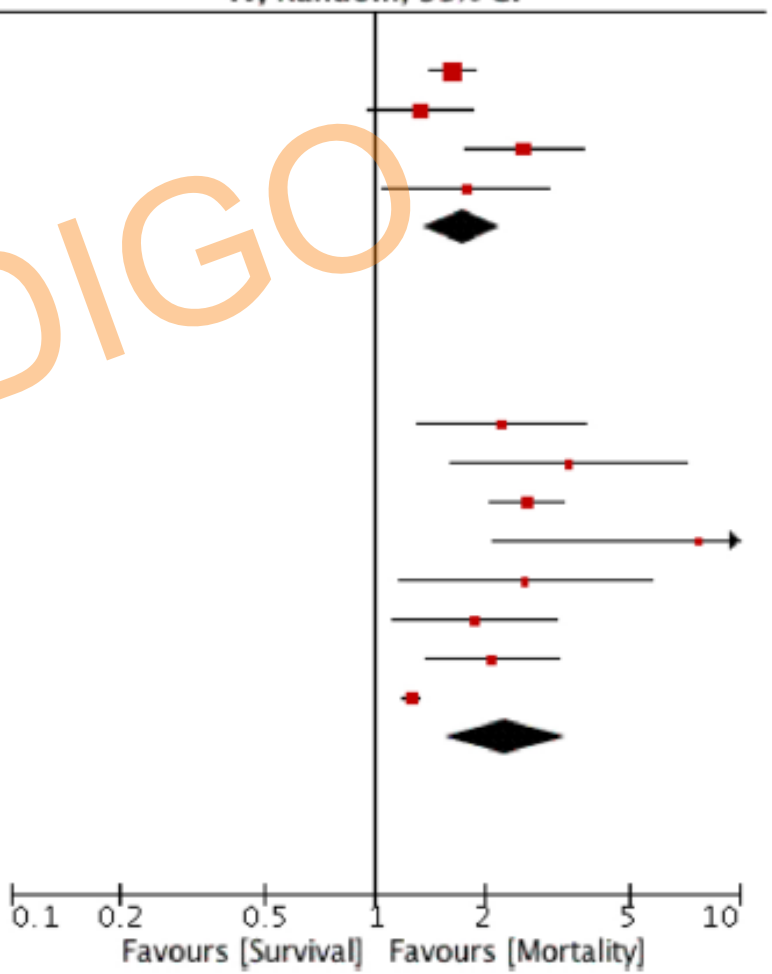
Chamney P et al., *Am J Clin Nutr.* 2007 Jan;85(1):80-9



Fluid Volume & Outcomes

- Bioimpedance Spectroscopy in ESRD (PD and HD)
  - Prognostic Importance

Study or Subgroup	Weight	Hazard Ratio IV, Random, 95% CI
3.1.1 Phase Angle (PA) – For every 1 degree decrease in PA		
Beberashvilli 2014a	39.2%	1.64 [1.42, 1.90]
Beberashvilli 2014b	24.8%	1.33 [0.96, 1.85]
Koh 2011	21.8%	2.56 [1.76, 3.73]
Shin 2017	14.3%	1.79 [1.05, 3.03]
Subtotal (95% CI)	**100.0%**	**1.74 [1.37, 2.21]**
Heterogeneity: Tau² = 0.03; Chi² = 7.03, df = 3 (P = 0.07); I² = 57%		
Test for overall effect: Z = 4.49 (P < 0.00001)		
3.1.2 Overhydration Index – cut off of OH >15%		
Caetano 2016	12.9%	2.22 [1.30, 3.80]
Chazot 2012	10.4%	3.41 [1.62, 7.17]
Dekker 2017	16.3%	2.62 [2.08, 3.30]
Drepper 2016	5.6%	7.82 [2.10, 29.07]
Kim 2015	9.8%	2.58 [1.16, 5.74]
Onofriescu 2015	13.2%	1.87 [1.12, 3.13]
Wizemann 2009	14.4%	2.10 [1.39, 3.18]
Zoccali 2017	17.3%	1.26 [1.19, 1.33]
Subtotal (95% CI)	**100.0%**	**2.28 [1.56, 3.34]**
Heterogeneity: Tau² = 0.22; Chi² = 62.53, df = 7 (P < 0.00001); I² = 89%		
Test for overall effect: Z = 4.27 (P < 0.0001)		



For the Body Composition Monitor:

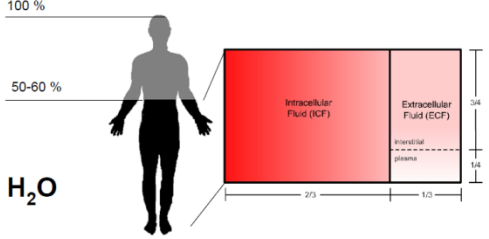
- 9 RCTs with BCM only 2156 patients (HD + PD)

- 38 non-RCTs with BCM 104,892 patients (HD, PD, CKD)

(only studies with >100 patients and reporting cardiovascular outcomes) (some patients are included twice)

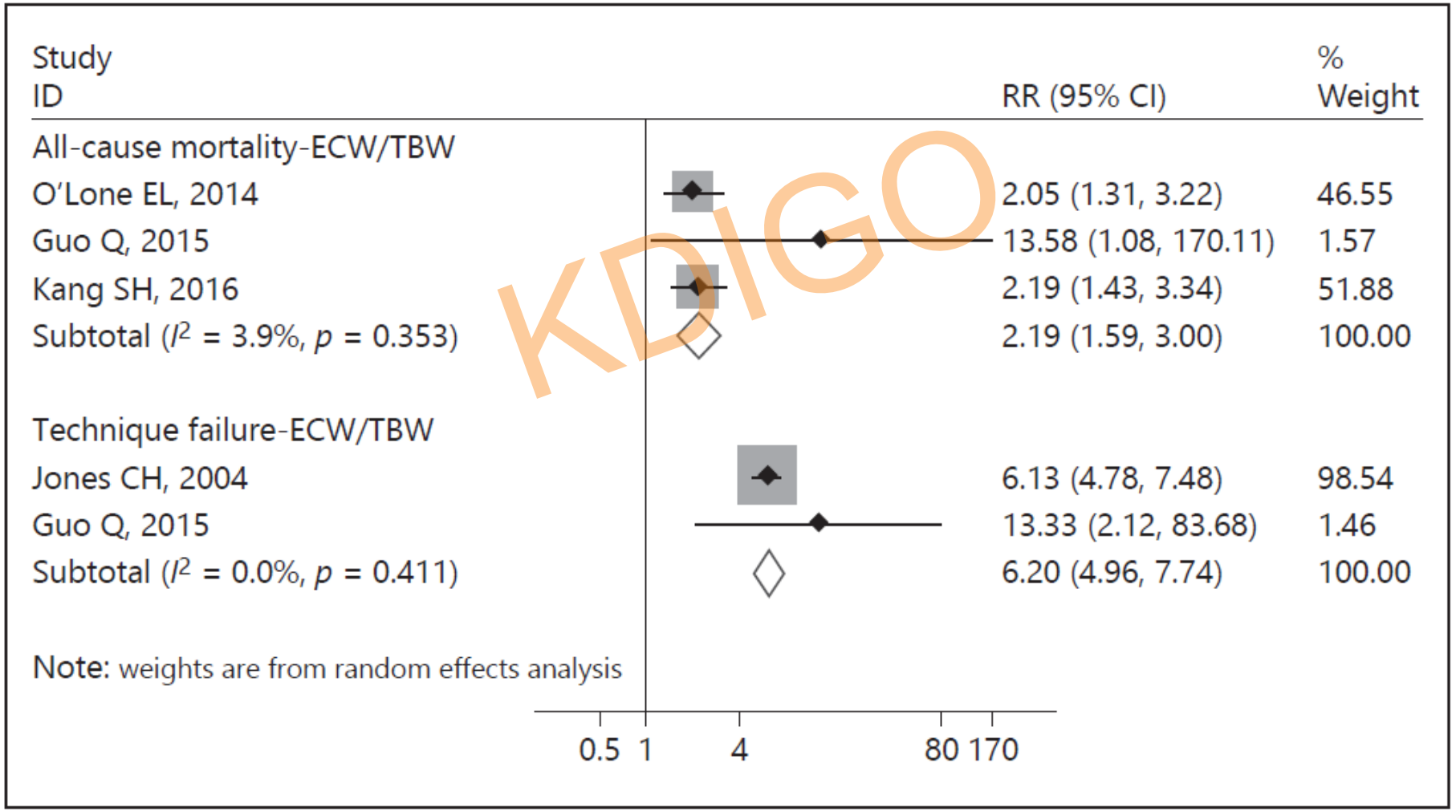
P. Wabel, personal communication

Tabinor M et al., *Sci Rep.* 2018 Mar 13;8(1):4441

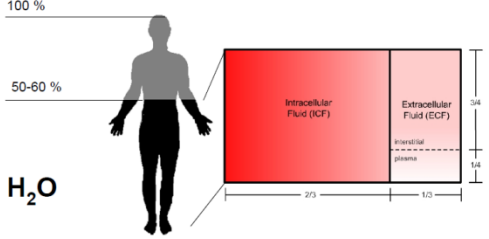


Fluid Volume & Outcomes

- **Bioimpedance Spectroscopy in ESRD (PD only)**
  - **Prognostic Importance**



Shu Y et al., *Blood Purif.* 2018;46(4): 350-358



Bioimpedance Spectroscopy & Outcomes Which Predictors?

Study or Subgroup	Weight	Hazard Ratio IV, Random, 95% CI	Hazard Ratio IV, Random, 95% CI
3.1.1 Phase Angle (PA) – For every 1 degree decrease in PA			
3.1.2 Overhydration Index – cut off of OH >15%			

Study ID	RR (95% CI)	% Weight
All-cause mortality-ECW/TBW		

Tabinor M et al., *Sci Rep.* 2018 Mar 13;8(1):4441

Shu Y et al., *Blood Purif.* 2018; 46(4):350-358

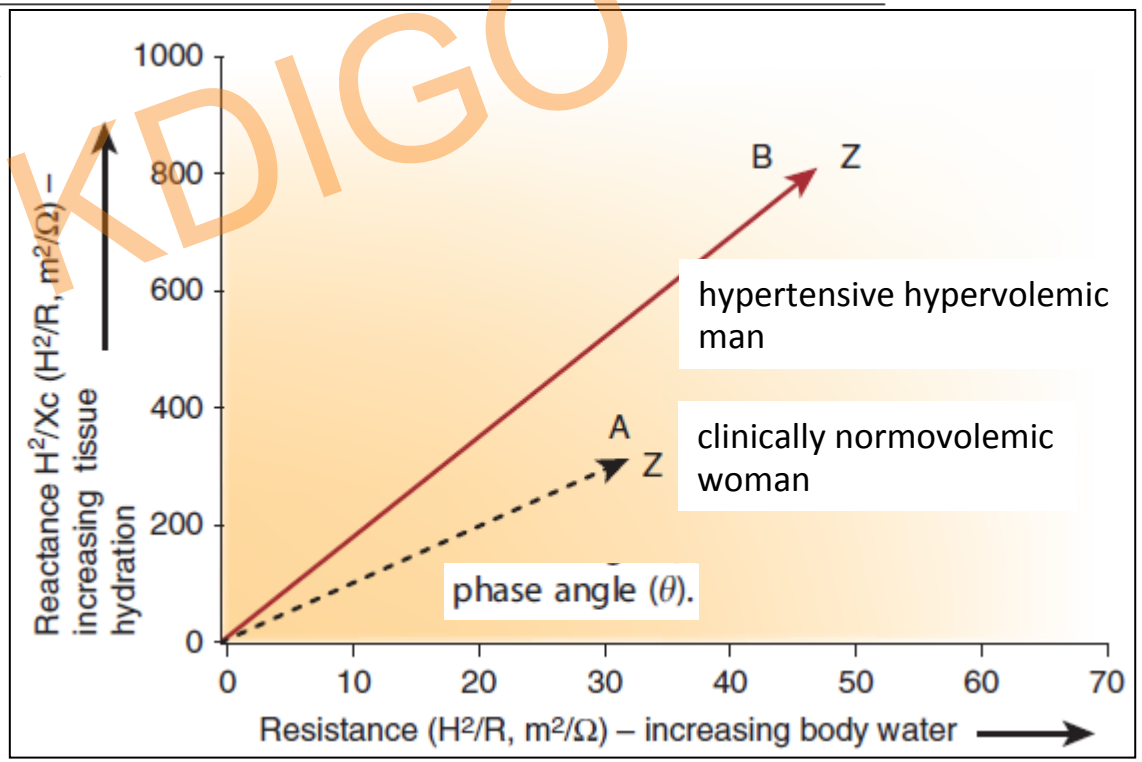
Type of approach	Method of normalization	Example of device(s)	Advantages and normal values	Limitations
Vector plot of resistance (*R*) and reactance (*Xc*) (see Figure 1) to show vector length (*Z*) and phase angle (θ).	Height, either as *R*/H and *Xc*/H or as H^2/R and H^2/Xc. This method inverts the relationship but is easier to use.	RJL Systems or BIA 2000-S	Large database of normal values showing the effect of age, sex, and BMI (15,605 children and 213,294 adults).[41] Simple single-frequency device required, making no assumptions about absolute volumes. Both *Z* and θ are strong independent predictors of survival in dialysis.[6] This method has been validated by Piccoli in hemodialysis patients.[7]	Not intuitive to use clinically. Interpretation of a change in vector requires an understanding of how this reflects a change in weight, which may be fat, fluid, or muscle. Normal confidence ellipses can be shown on the vector plot as a guide[7] but may not help in renal failure.
ECW/TBW ratio (sometimes expressed as ECW/ICW)	Usually not normalized, but expressed as ratio; strictly should be normalized to sex and age.	All devices (single or multifrequency)	Easy to use, intuitive, and well validated as a predictor of survival. Using the Lindley-Lopot formula derived from healthy subjects that gives an age/sex-adjusted prediction:[40] ±5% of predicted value (= ±2 s.d.) is considered abnormal.	Because it is a ratio either componen could be abnormal. Small validation group and Lindley-Lopot formula only applies to Xitron Hydra device.
ECW volume	Height or weight by gender	All devices (single or multifrequency)	Easy to use. In a clinically normovolemic group of dialysis patients, the 80th percentile values for ECW/weight were 0.245 and 0.232 l/kg and for ECW/height were 10.96 and 9.13 l/m in men and women, respectively.	No independent survival data. ECW/h is reduced in renal failure compared with healthy subjects. Small validation group applicable to Xitron Hydra device only.
OH index	ECW volume	BCM	Provides an easy-to-understand metric by using the BIA-derived ECW and ICW volumes and applying the normal hydration constants for lean and fat tissue to determine excess or reduced hydration.[5,9] An OH/ECW index above or below 15% is abnormal. Recent RCT in HD patients demonstrating improved LVH using this approach.[32]	Early studies suggest that using this measure to guide fluid management in HD patients improved blood pressure and cardiac parameters. Data linking to clinical end points in PD patients are awaited.

Vector length
Phase angle

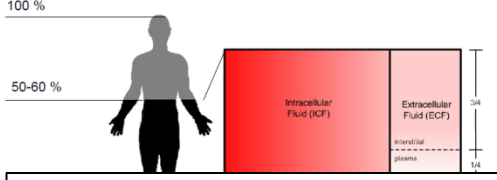
ECW/TBW

ECW volume

OH index



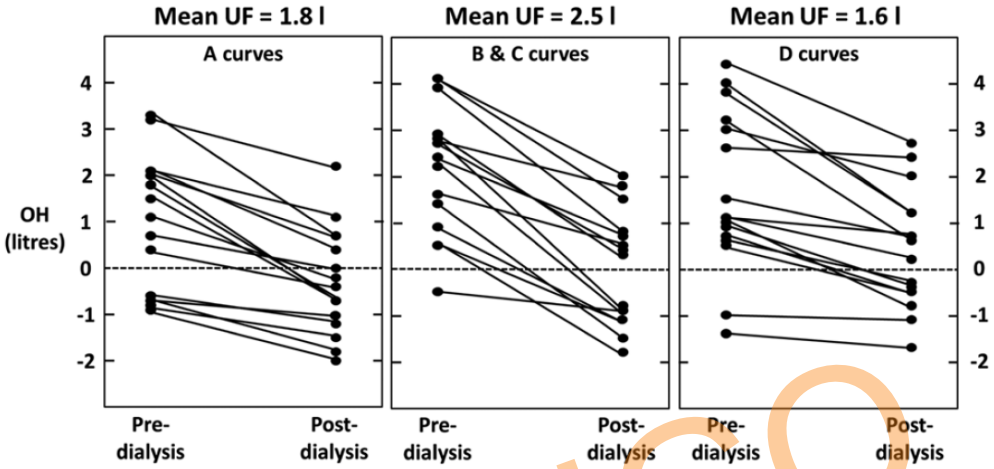
Davies SJ & Davenport A, *Kidney Int* 2014 Sep;86(3):489-96



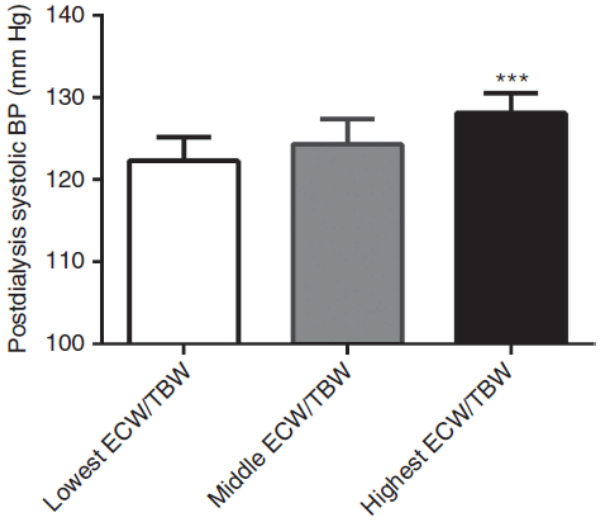
Fluid Volume Assessment

- Bioimpedance and…

- Pedal Edema
- Chest X-ray
- Inferior Vena Cava Diameter
- Biochemical Markers
- Lung Comets
- (Diagnostic) Relative Blood Volume Monitoring
- Dual-energy X-ray absorptiometry (=DXA)
- Magnetic Resonance Imaging (MRI)
- Echocardiography
- Pulmonary Artery Pressure
- Pulse Pressure
- Stroke Volume Variation
- Leg Raising Test
- Blood Pressure



Keane DF et al., *ASAIO J.* 2018 Nov/Dec;64(6):812-818



Nongnuch A et al., *Kidney Int.* 2015 Feb;87(2):452-7

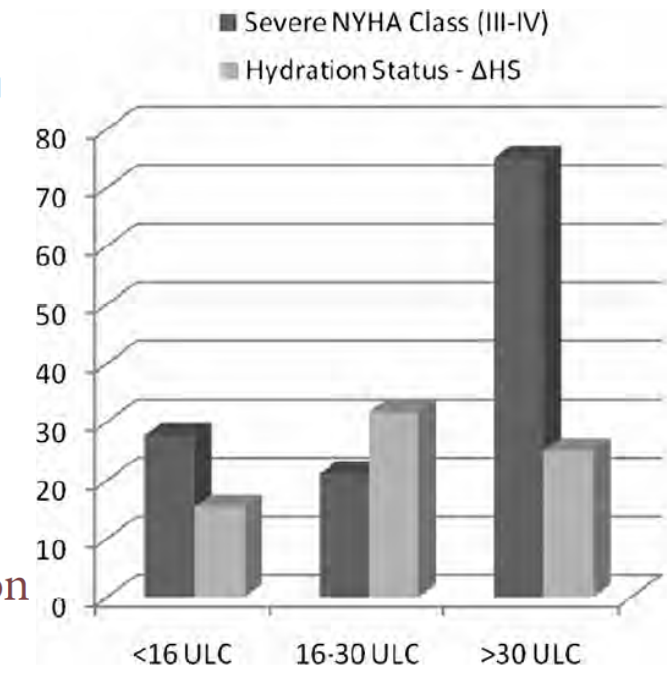
KDIGO

Do pre-haemodialysis estimates of extracellular volume excess using bioimpedance and N terminal brain natriuretic peptide correlate with cardiac chamber size measured by magnetic resonance imaging ?

Yoowannakul MD et al., *Ther Apher Dial.* 2018 Nov 23

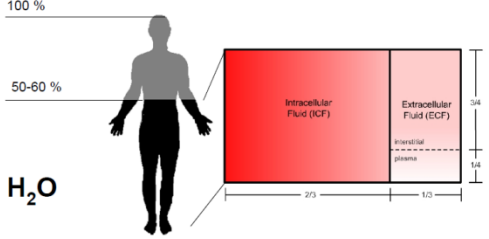
Comparison of Multifrequency Bioelectrical Impedance Analysis and Dual-Energy X-ray Absorptiometry Assessments in Outpatient Hemodialysis Patients

Fürstenberg A & Davenport A, *Am J Kidney Dis.* 2011 Jan;57(1):123-9

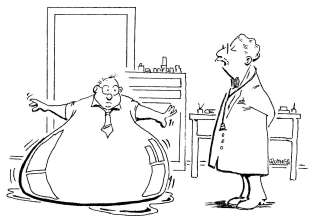


Predicting mortality in haemodialysis patients: a comparison between lung ultrasonography, bioimpedance data and echocardiography parameters

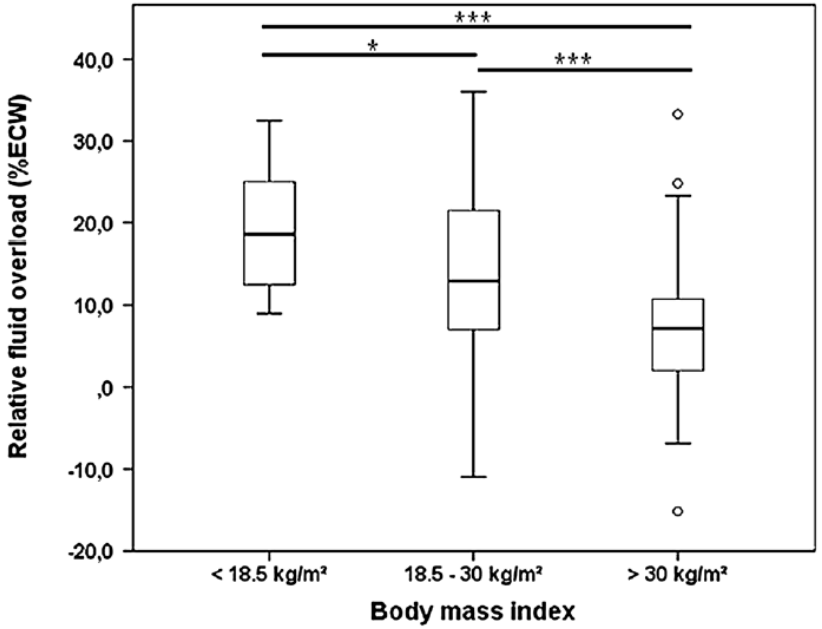
Siriopol D et al., *Nephrol Dial Transplant.* 2013 Nov;28(11):2851-9

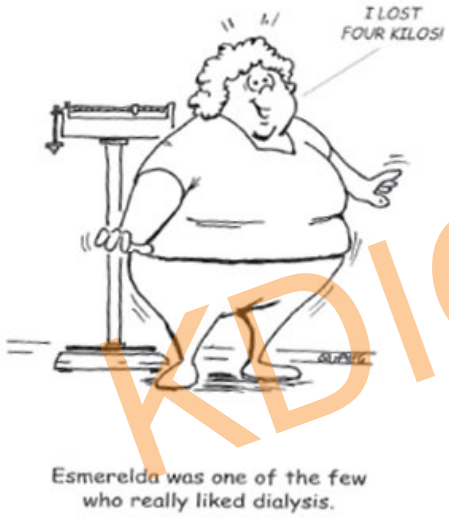


Fluid Volume Assessment Reveals…



Fluid Overload and BMI inversely associated: Explanation for ‚Reverse Epidemiology'?



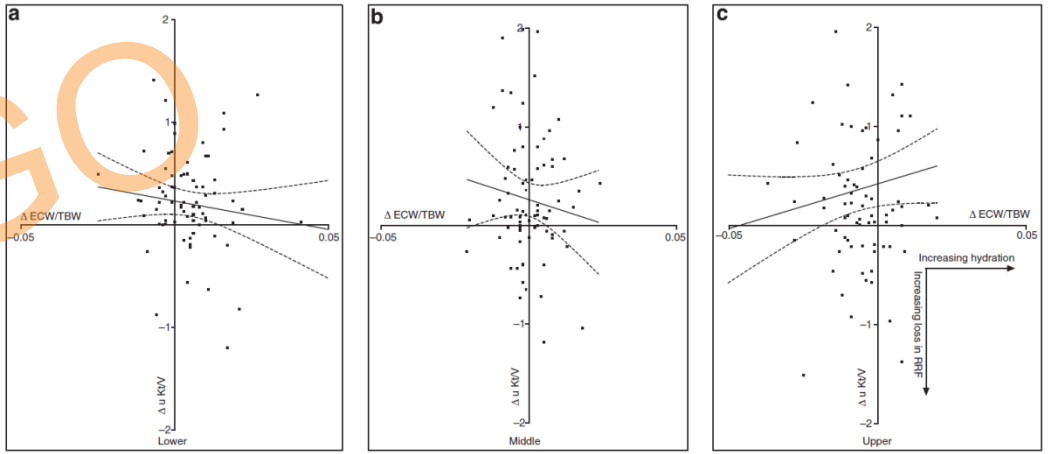


Antlanger, M et al., *BMC Nephrology* 2013, 14:266, similar results published by **Ribitsch W, et al.**, *Clin Nephrol* 2012; 77: 376-82 & **Wizemann V, et al.**, *Nephrol Dial Transplant* 2009; 24: 1574-9

The Effect of Racial Origin on Total Body Water Volume in Peritoneal Dialysis Patients

Davenport A et al., *Clin J Am Soc Nephrol.* 2011 Oct;6(10):2492-8

Extracellular volume expansion, measured by multifrequency bioimpedance, does not help preserve residual renal function in peritoneal dialysis patients



McCafferty K et al., *Kidney Int.* 2014 Jan;85(1):151-7

Impact of fluid status and inflammation and their interaction on survival: a study in an international hemodialysis patient cohort

OPEN

Marijke J.E. Dekker[1,2], Daniele Marcelli[3], Bernard J. Canaud[3], Paola Carioni[3], Yuedong Wang[4], Aileen Grassmann[3], Constantijn J.A.M. Konings[2], Peter Kotanko[5,6], Karel M. Leunissen[1], Nathan W. Levin[5,6], Frank M. van der Sande[1], Xiaoling Ye[5], Vaibhav Maheshwari[5], Len A. Usvyat[5,7] and Jeroen P. Kooman[1]; for the MONDO Initiative

Summary 1: Harnessing Technology To Assess Volume [Dry Weight]

Tools to assess fluid status	Ultra-sound (lung; IVC)	Tracers	Bio-impedance	Bio-markers	Relative blood volume	Absolute blood volume (experimental)
Staff involvement	High	High	Medium	Low	Low	Low
Time requirement	Medium	High	Medium	Low	Low	Low
System costs	Medium	High	Medium	Medium	Low	Low
Between observer variability	High	Low	Low	Low	Low	Low
Within observer variability	Medium	Low	Low	Low	Low	Low
Invasiveness/ inconvenience	Medium	High	Medium	Low	Low	Low
Assessment frequency	Medium	Low	Medium	Medium	High	High
Correlation with fluid status	Medium	High	High	Medium	Medium	?
Direct / indirect marker	Indirect	Direct	Direct	Indirect	Indirect	Direct
Measurement Accuracy	Medium	High	High	High	High	?
Suitable for …	HD & PD	HD & PD	HD & PD	HD & PD	HD	HD

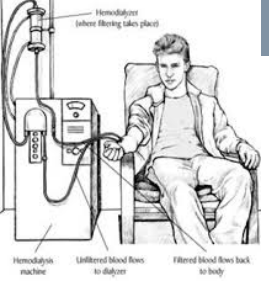
KDIGO

	Biochemical markers	Detection of lung "water" by chest ultrasound
Sensitivity to volume status	+/–	+
Accuracy of ECV	–	–
Reproducibility	+/–	+
Availability of endpoint	–	+/–
Ease of application	+	+
Applicability to PD & CKD	+	+

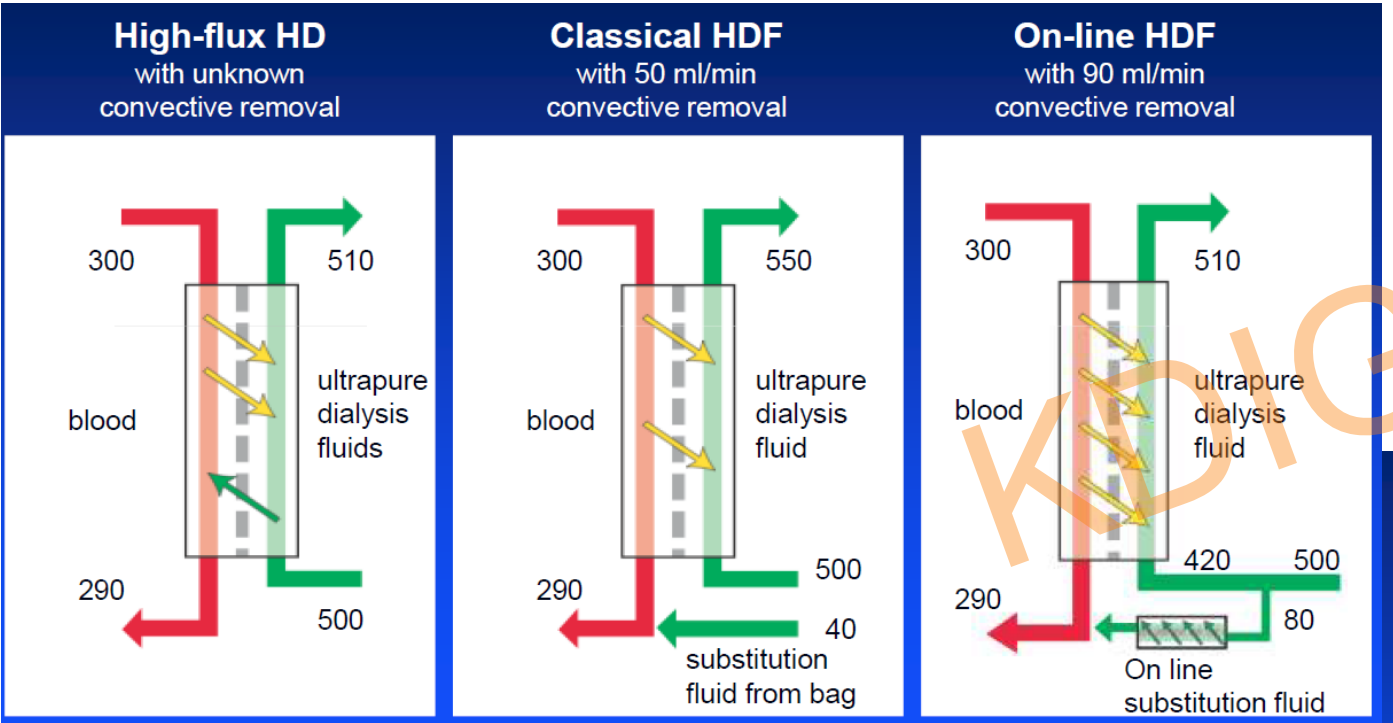
	Whole-body bioimpedance spectroscopy	Relative plasma volume monitoring
Sensitivity to volume status	+	+
Accuracy of ECV	+	–
Reproducibility	+	+/–
Availability of endpoint	+	+/–
Ease of application	+	+
Applicability to PD & CKD	+	–

Courtesy Peter Kotanko

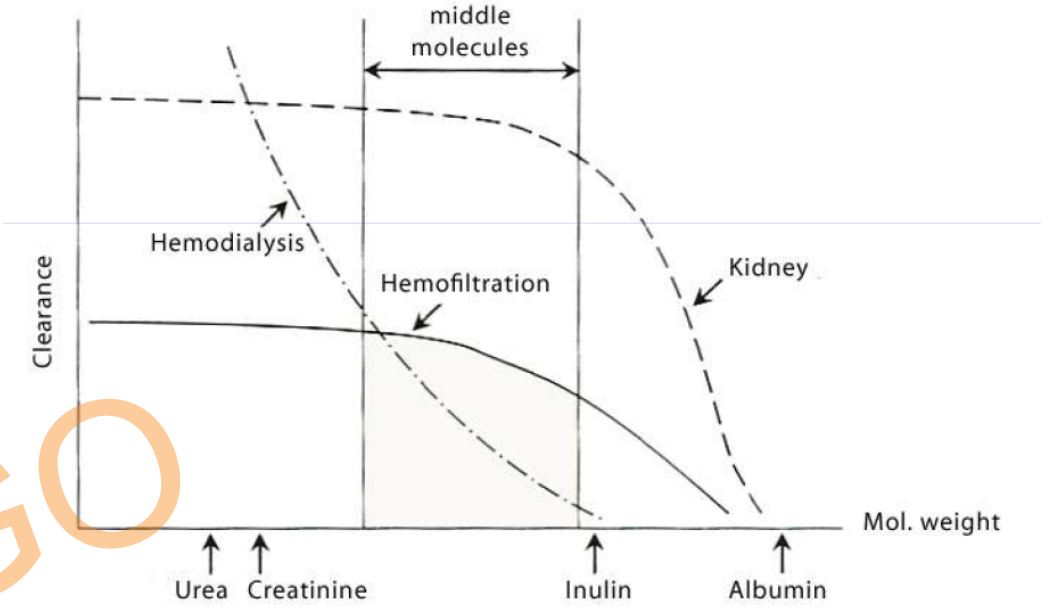
Hecking M et al., *Semin Dial.* 2015 May-Jun;28(3):242-7

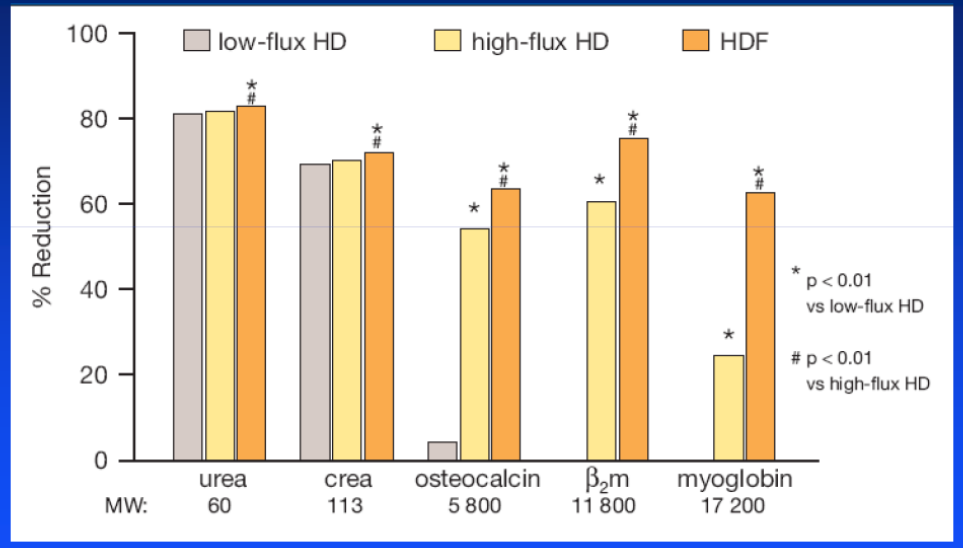


Intradialytic Volume Management: HF/HDF vs HD ('Hot Topic')



NDT Plus 2010; 3: 8-16





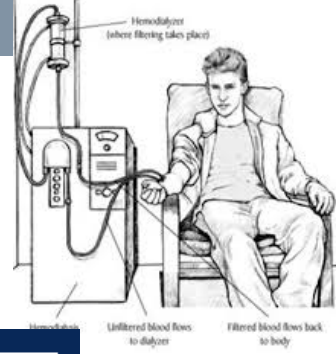
N=23, 3 treatment / mode

Same Q_B, Q_D, t, ΔBW and filter size

Am J Kidney Dis 2002; 40: 582

Courtesy Peter J. Blankestijn

Intradialytic Volume Management: Cooling



According to the original observation by Maggiore et al. [19] that dialysate temperature set at about 35°C affords a better haemodynamic stability than the standard dialysate temperature of 37–38°C, an alternative hypothesis to explain the reduction of hypotension episodes during online HDF is suggested by Donauer et al. [20], who identified blood cooling as the main blood pressure-stabilizing factor in online HDF. During online HDF, an enhanced energy loss within the extracorporeal system occurred, despite identical temperature settings for dialysate and substitution fluids. As a result, the blood returning to the patient was cooler during online HDF than during HD. Moreover, the mean blood temperature was lower in online HDF, even in the patient's circulation, and blood volume was significantly more reduced. The incidence of symptomatic hypotension was similar to that of online HDF by using cooler temperature-controlled HD.

Beneficial Effect of HDF, Low Temp HD, (and Iso-UF): Explained by Cooling/Energy Transfer

J Am Soc Nephrol 11: 1512–1517, 2000

Energy Transfer Is the Single Most Important Factor for the Difference in Vascular Response between Isolated Ultrafiltration and Hemodialysis

FRANK M. VAN DER SANDE,* ULRICH GLADZIWA,† JEROEN P. KOOMAN,* GEORGE BÖCKER,† and KAREL M. L. LEUNISSEN*
*Department of Internal Medicine and Nephrology, University Hospital Maastricht, The Netherlands; and †University of Witten/Herdecke, Germany.

Nephrol Dial Transplant (2003) 18: 1616–1622
DOI: 10.1093/ndt/gfg206

Nephrology Dialysis Transplantation

Original Article

Reduction of hypotensive side effects during online-haemodiafiltration and low temperature haemodialysis

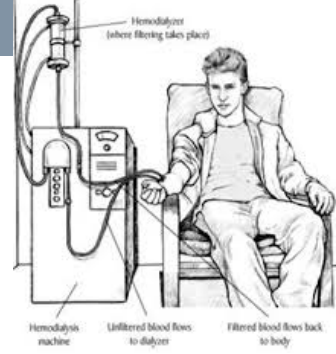
Johannes Donauer[1], Christoph Schweiger[1], Brigitta Rumberger[1], Bernd Krumme[2] and Joachim Böhler[2]

[1]Department of Nephrology, University Hospital Freiburg and [2]Deutsche Klinik für Diagnostik, Division of Nephrology, Wiesbaden, Germany

Locatelli F, *Blood Purif*. 2015; 40 Suppl 1:24-9

Courtesy Thomas Roy

Intradialytic Volume Management: Isolated UltraFiltration



From Isolated Ultrafiltration to Blood-Temperature-Controlled Feedback: An Odyssey Started by Jonas Bergström

Jeroen P. Kooman[a] Frank van der Sande[a] Karel Leunissen[a]
Stanley Shaldon[b]

[a]University Hospital Maastricht, Maastricht, The Netherlands;
[b]25 Le Michelangelo 7, Avenue des Papalins, Monaco, Monte Carlo

It is tempting to read, in the commentary of Jonas Bergström himself, that the improved haemodynamic stability during isolated ultrafiltration was actually discovered in 1973 by a technical fault of the dialysis module, which had been in bypass position without alarming, meaning that no dialysate had passed during the treatment. During this faulty treatment, fluid removal was remarkably well tolerated in a patient who used to experience symptomatic hypotension during every treatment. Due to Bergström's combination of clinical and scientific interest, this single observation was translated into a structured research program. The paper published in the

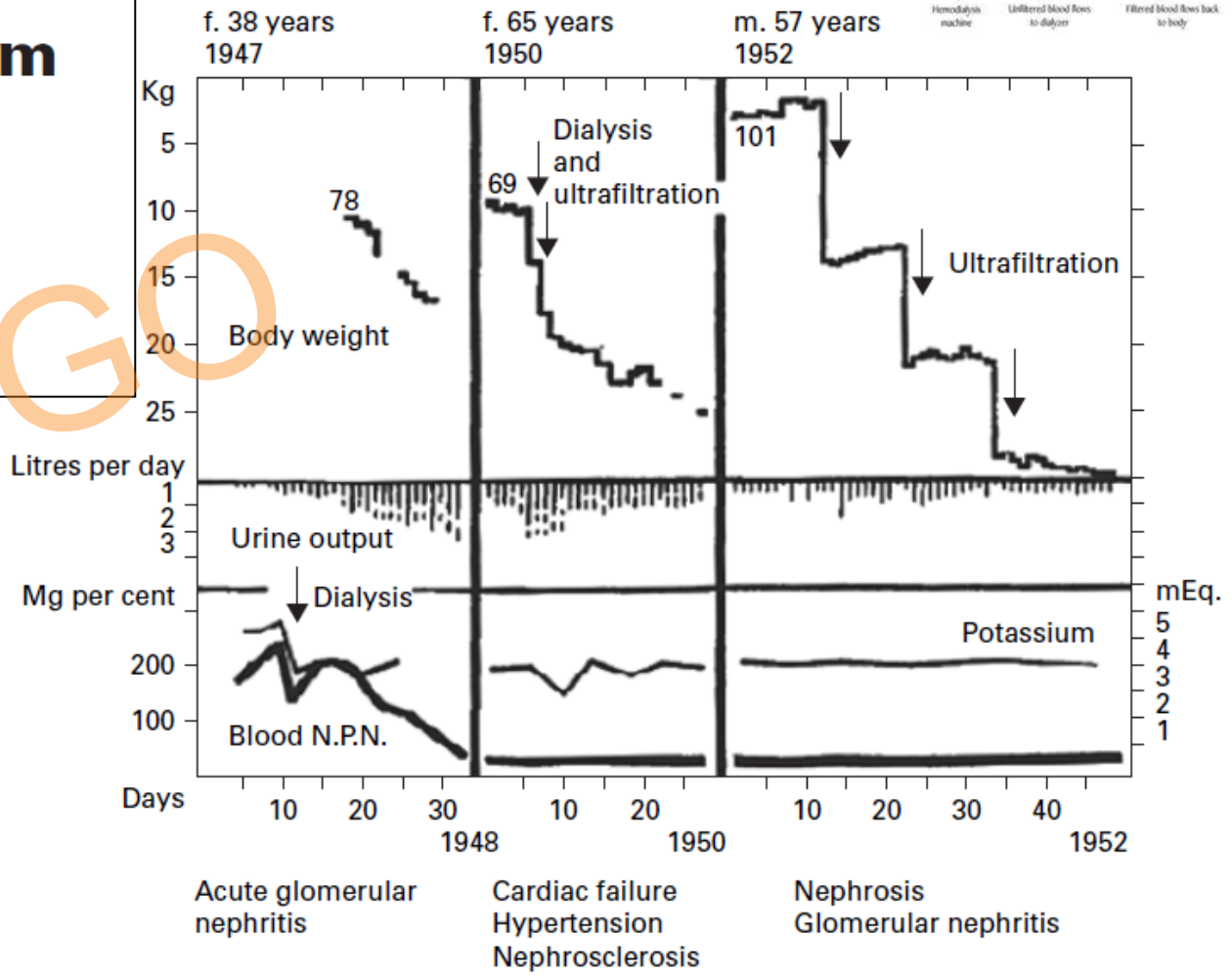


Fig. 1. Original description of isolated ultrafiltration by Alwall. Illustration modified

Intradialytic Volume Management: Isolated UltraFiltration

Table 3. Individual values for changes in FVR, VT and HR

Patient	Dialysate temperature: 37.5°C						Dialysate temperature: 35.0°C					
	FVR		VT		HR		FVR		VT		HR	
	UF	HD	UF	HD	UF	HD	UF	HD	UF	HD	UF	HD
1	+731	+1177	+3.2	+2.1	−7	0	+1142	−838	−0.8	+0.7	−6	+3
2	+1372	+180	+21.0	−21.1	−4	+5	+1676	−1016	+25.2	−10.2	−7	+3
3	+3671	−1983	+6.9	−6.2	+1	+22	+2908	+2581	+3.2	+3.0	+7	−6
4	+1058	−164	+2.9	−15.1	−5	+9	+788	+584	+5.2	−3.0	−1	−3
5	+1221	−625	+11.2	−11.3	−12	+7	+2437	−1077	+12.5	−5.7	−6	+1
6	+877	−266	+3.8	−5.2	−2	+5	+210	−463	+1.9	−1.0	−4	−8
7	+613	−320	+5.9	−5.1	−6	0	−214	+181	+3.5	−0.5	−6	−5
8	+273	+471	+2.8	−1.2	0	0	−71	+1498	−5.8	+5.8	+1	−4
9	+1537	+202	+2.8	−6.4	−4	−2	−544	+29	−4.5	−3.2	+1	−7
10	+1079	+283	+5.4	−0.8	−9	+7	−75	+364	+4.2	−0.8	+5	−5
11	+834	+2181	+10.2	−4.5	−1	+5	+1051	+2288	−0.5	−1.5	+2	−2
12	+1435	+249	+4.2	−0.2	+2	0	+804	+1166	+2.4	+3.3	+5	−4

FVR (mmHg/ml/100 ml/s); VT (mmHg/ml/100 ml); HR (beats/min).
Patients 1–6 UF–HD; patients 7–12 HD–UF.

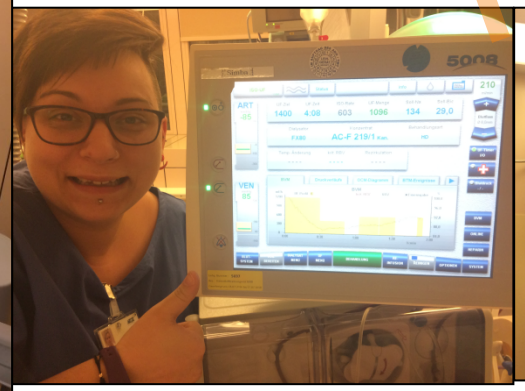
Forearm Vascular Resistance

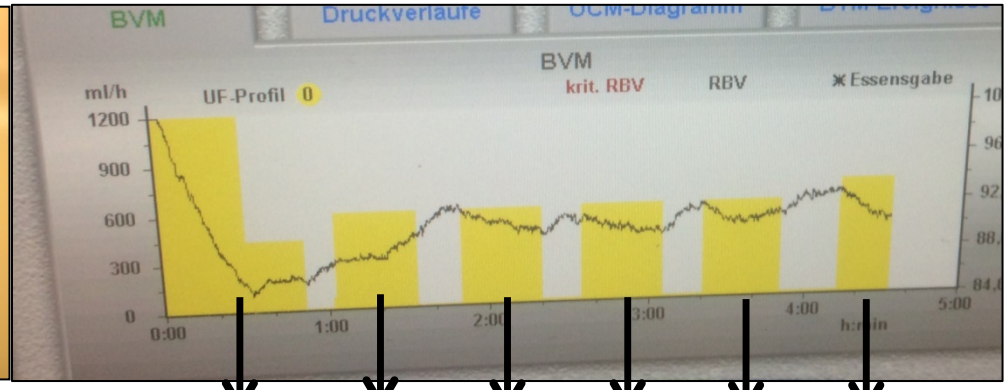
Vascular Tone

Vascular reactivity during haemodialysis and isolated ultrafiltration: thermal influences

VanKuijk WHM et al., *Nephrol Dial Transplant* 1995 10:1852-58

Conclusions. We conclude that differences in cardiovascular reactivity between isolated ultrafiltration and combined ultrafiltration–haemodialysis are only partially explained by differences in the extracorporeal blood temperature. In addition, especially venous reactivity is improved by lowering the dialysate temperature.



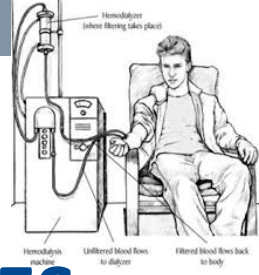


Pictures shown with permission

6 times Iso-UF (at 2000 mL/hour)

Why Is There NO Programed Profile For Isolated UltraFiltration In Any Dialysis Machine?

Intradialytic Volume Management:



Dialysate Composition Sodium

↓

Covered By Other Group

Sodium Profiles (Na-Modelling)

↓

Salt, the Neglected Silent Killer

Stanley Shaldon* and Joerg Vienken†

The Evils of Intradialytic Sodium Loading

Stephan Thijssen[a,b] · Jochen G. Raimann[a,b] · Len A. Usvyat[a] · Nathan W. Levin[a,b] · Peter Kotanko[a,b]

[a]Renal Research Institute, and [b]Beth Israel Medical Center, New York, N.Y., USA

Blood Purification

Blood Purif 2006;24:63–66
DOI: 10.1159/000089439

Salt – A Potential 'Uremic Toxin'?

Eberhard Ritz Ralf Dikow Christian Morath Vedat Schwenger

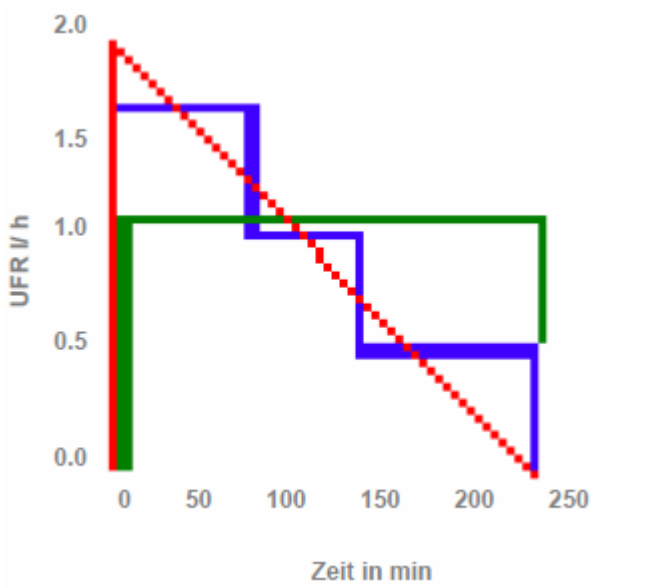
Department of Internal Medicine, Ruperto Carola University Heidelberg, Heidelberg, Germany

No Time – Will Be Discussed In Group 3

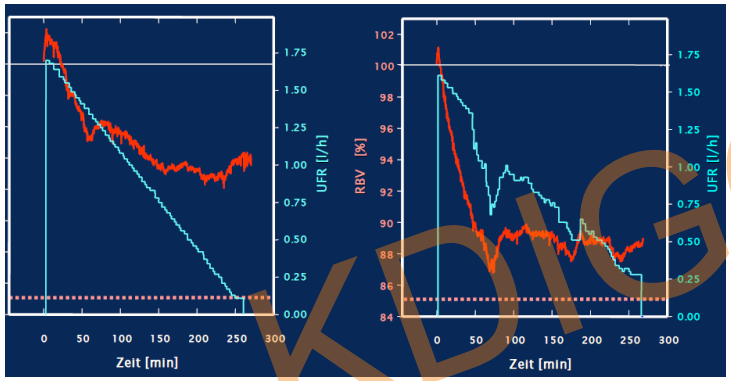
Intradialytic Volume Management:

Ultrafiltration Rate Profiles

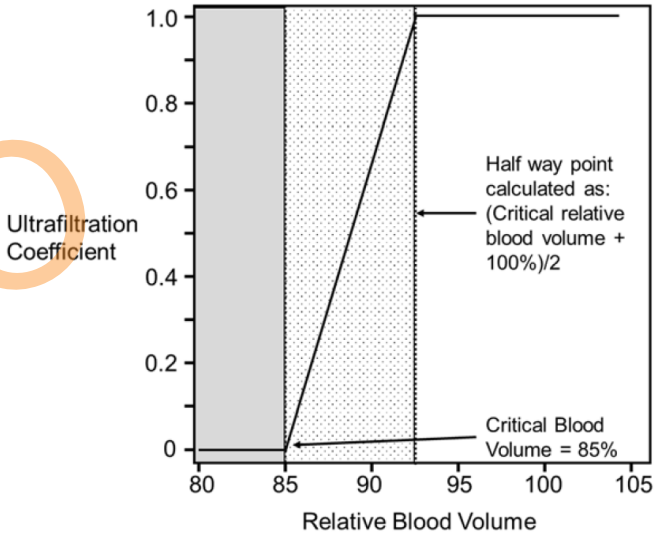
Relative Blood Volume-Controlled Feedback of the Ultrafiltration Rate



Constant UFR
Stepwise UFR profile
"Auto-UFR"



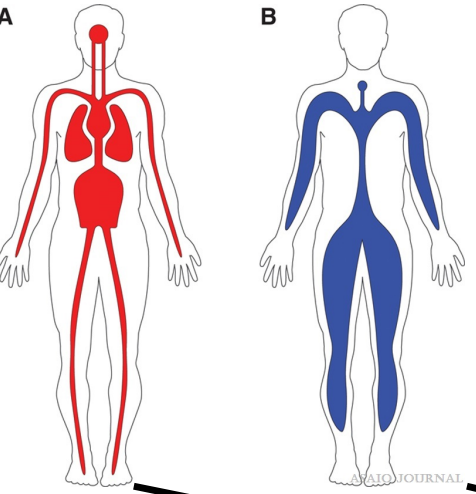
One Patient, 2 Subsequent Treatments



Leung KCW, *Clin J Am Soc Nephrol.* 2017 Nov 7;12(11): 1831-1840

"The actual ultrafiltration rate is the maximum ultrafiltration rate multiplied by a variable known as the ultrafiltration coefficient (ranging from zero to one). At the beginning of HD, the ultrafiltration coefficient equals one until the relative blood volume is halfway towards the critical relative blood volume. Once past the halfway point, the ultrafiltration coefficient decreases linearly (thus slowing the actual ultrafiltration rate) until the critical relative blood volume is reached, when the coefficient equals zero to effectively stop ultrafiltration."

Intradialytic Volume Management: A Case For Absolute Blood Volume Measurements?



Feedback Control in Hemodialysis—Much Ado about Nothing?

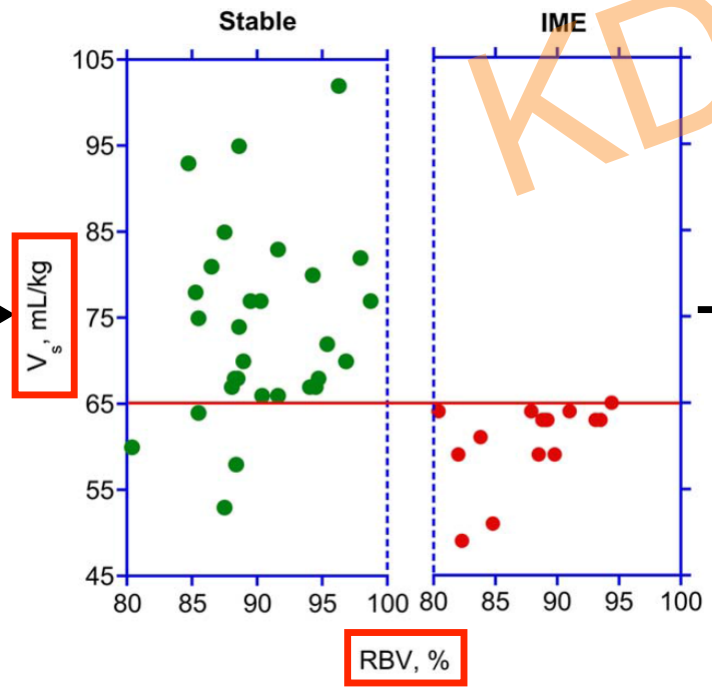
Hecking M & Schneditz D, *Clin J Am Soc Nephrol.* 2017 Nov 7;12(11):1730-1732

[…] "the futility to controlling intravascular volume using relative changes can be compared with a room thermostat controlling the temperature change rather than the absolute room temperature: the resulting temperature could be anything."

Total body volume by bioimpedance
Total blood volume by dilution method

Schneditz D et al., *ASAIO J.* 2018 Nov/Dec;64(6): 697-700

Absolute blood volume*: measured by dialysate dilution



Target weight was increased or decreased in 32 patients.

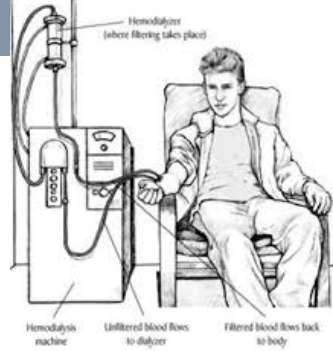
	Baseline	Follow-up	P
Patients with IME	24	3	<0.001
Frequency of all IME (%)	66 (12.2)	5 (0.9)	<0.001
Symptomatic hypotension	47	3	<0.001
Cramps	16	2	<0.001
Loss of voice	3	0	

Kron S et al., *Hemodial Int.* 2018 Nov 7;12(11):1730-1732

***Gold Standard:**

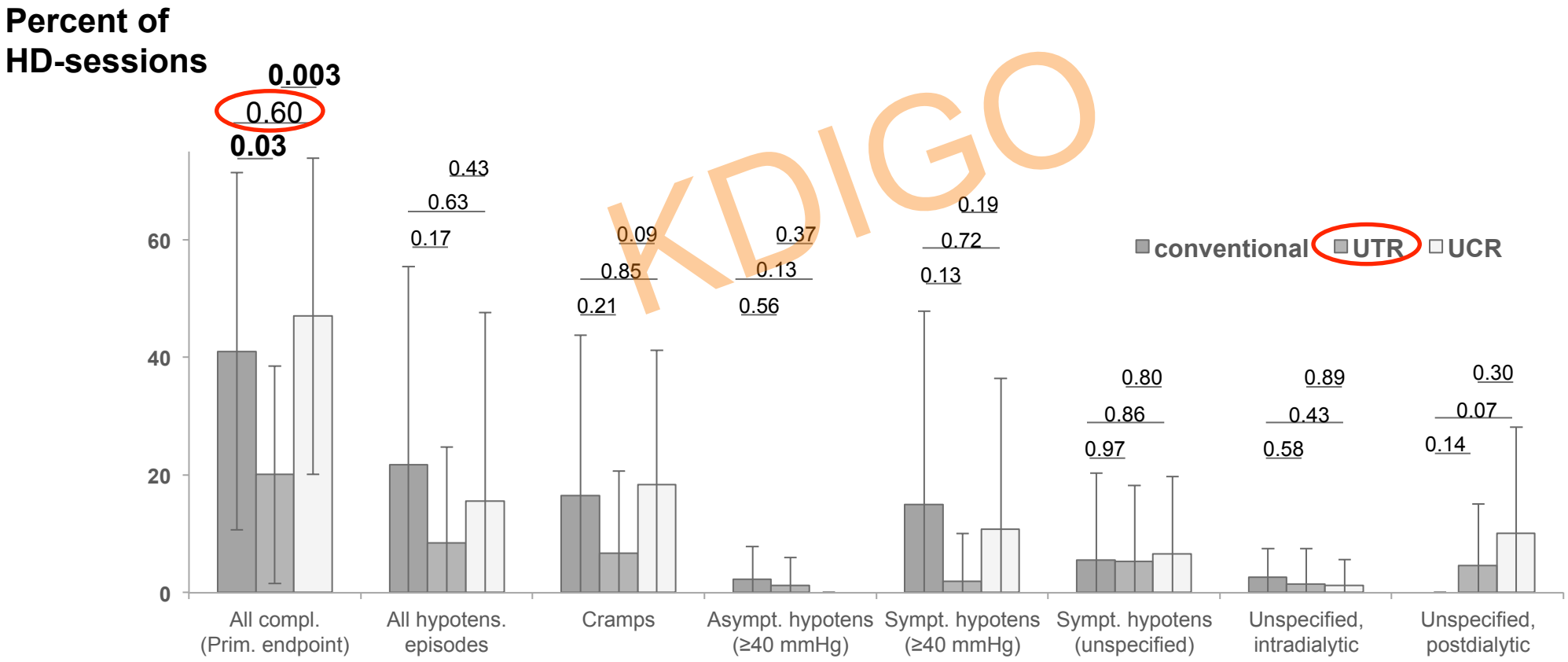
- **Total Blood Volume: ^{131}I-labeled albumin + ^{51}Cr-labeled red cells; Indocyanine Green**

Intradialytic Volume Management: Several Techniques Combined



Is the Dry Weight ‚Reducable'? Can Technology Help?

Blood volume-monitored regulation of ultrafiltration in fluid-overloaded hemodialysis patients



Antlanger M. et al., *BMC Nephrol*. 2017 Jul 17;18(1):238.

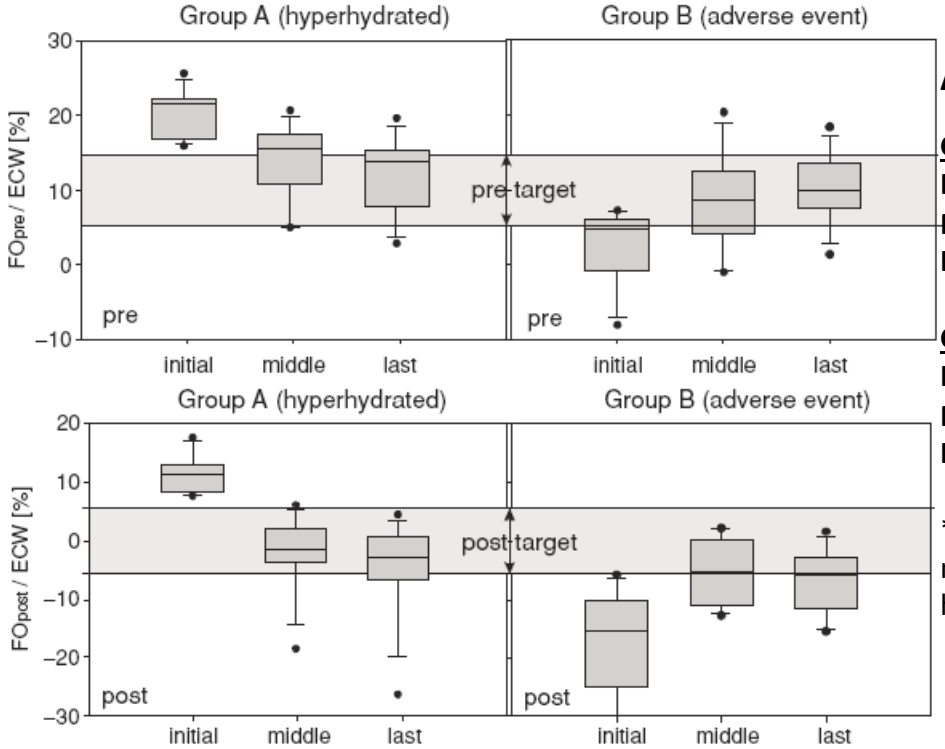
(1) Volume [Dry Weight] Assessment; (2) Volume Management In The DOPPS (2009-2012, Medical Director Survey)

Facility level practices	All facilities (n = 273)	Australia/New Zealand (n = 14)	Canada (n = 18)	Europe (n = 120)	Japan (n = 58)	US (n = 63)
Fluid Volume Management						
Protocol that specifies how often to assess dry weight in most pat's	*67 (25%)*	*4 (29%)*	*1 (6%)*	*28 (23%)*	*26 (46%)*	*8 (13%)*
Routine orthostatic BP measurement to assess dry weight	*157 (58%)*	*11 (79%)*	*14 (78%)*	*55 (46%)*	*29 (51%)*	*48 (76%)*
Routine on-line volume indicator to assess dry weight	*57 (21%)*	*2 (15%)*	*6 (33%)*	*35 (30%)*	*3 (5%)*	*11 (18%)*
Routine bio-impedance study to assess dry weight	*13 (5%)*	*0 (0%)*	*0 (0%)*	*11 (9%)*	*1 (2%)*	*1 (2%)*
Routine on-line volume indicator AND bio-impedance study	*6 (2%)*	*0 (0%)*	*0 (0%)*	*5 (4%)*	*0 (0%)*	*1 (2%)*
Policy that limits fluid removal during dialysis session	93 (35%)	6 (43%)	5 (28%)	44 (37%)	20 (36%)	18 (29%)
Performs isolated ultrafiltration	192 (73%)	9 (69%)	14 (82%)	95 (80%)	32 (56%)	42 (71%)
Management of IntraDialytic Hypotension						
Protocol for managing IDH	128 (50%)	8 (57%)	10 (56%)	48 (45%)	23 (40%)	39 (66%)
Routine sodium modeling/profiling to limit or prevent IDH	118 (43%)	1 (7%)	16 (89%)	53 (44%)	5 (9%)	43 (68%)
Routine lower dialysate temperature to limit or prevent IDH	128 (47%)	6 (46%)	14 (78%)	73 (61%)	6 (11%)	29 (46%)

Dasgupta I et al., *Clin J Am Soc Nephrol* in press

Another Way of Harnessing Technology: Strategy Of Volume Management (Dialysis Planing)

One-Year, Single Center Experience



Adverse events*

Group A
Initial: 2.1%
Middle (6 months post): 2.3%
Last (12 months post): 1.4%

Group B
Initial: 25.7%
Middle (6 months post): 3.5%
Last (12 months post): 6.9%

*"Nursing interventions necessary, e.g. symptomatic hypotension and cramps"

Machek P et al., *Nephrol Dial Transplant* 2010; 25: 538-44

Ultrafiltration Rates and the Quality Incentive Program: Proposed Measure Definitions and Their Potential Dialysis Facility Implications

Flythe J et al., *Clin J Am Soc Nephrol.* 2016 Aug 8;11(8):1422-33

US: From Data Analysis to Policy

Rapid fluid removal during dialysis is associated with cardiovascular morbidity and mortality

Flythe J et al., *Kidney Int.* 2011 Jan;79(2):250-7

Disentangling the Ultrafiltration Rate–Mortality Association: The Respective Roles of Session Length and Weight Gain

Flythe J et al., *Clin J Am Soc Nephrol.* 2013 Jul;8(7):1151-61

Fluid Management: The Challenge of Defining Standards of Care

Flythe J et al., *Clin J Am Soc Nephrol.* 2014 Dec 5;9(12):2033-5

Associations of Posthemodialysis Weights above and below Target Weight with All-Cause and Cardiovascular Mortality

Flythe J et al., *Clin J Am Soc Nephrol.* 2015 May 7;10(5):808-16

Failed Target Weight Achievement Associates with Short-Term Hospital Encounters among Individuals Receiving Maintenance Hemodialysis

Assimon MM et al., *J Am Soc Nephrol.* 2018 Aug;29(8):21782188

Another Way of Harnessing Technology: Strategy Of Volume Management (Dialysis Planing)

DaVita. OFFICE OF THE Chief Medical Officer

601 Hawaii Street, El Segundo, CA 90245 : : 800.313.4872 : : davita.com/physicians

FluidWise Clinical Pathway 2.0 for Fluid Management
Nephrologist Memo

We are introducing version 2.0 of the FluidWise Clinical Pathway

- The FluidWise Clinical Pathway 1.0 was rolled-out in November 2014 with the goal of helping to reduce mortality and hospitalization.
- Version 2.0 includes ***the following changes***:
  - FluidWise Focus patients criteria has been expanded to include:
    - **Patients with frequent excessive interdialytic weight gain (new criteria)**
    - **Patients with frequent post weight above or below target weight (TW) by 1 kg or more (new criteria)**
    - FluidWise Most Vulnerable Patients
    - Transition of Care patients
  - Interventions for FluidWise Focus patients have been updated

The FluidWise Clinical Pathway 2.0 Highlights:

The Clinical Pathway provides a stepwise, role-specific guide to making the assessments and interventions necessary to manage fluid status in high-risk patients. Fluid management, as with the management of any chronic dialysis-related disease, is a function of the IDT (including the physician and patient). Assessments and interventions are presented in the Pathway in specified sequence, so that each member's action or contribution is then followed by the next in a step-wise fashion.

The FluidWise Clinical Pathway 2.0 categorizes ***FluidWise Focus*** patients into specific groups that that the IDT can use when considering interventions. The FluidWise Focus Report identifies these patients:

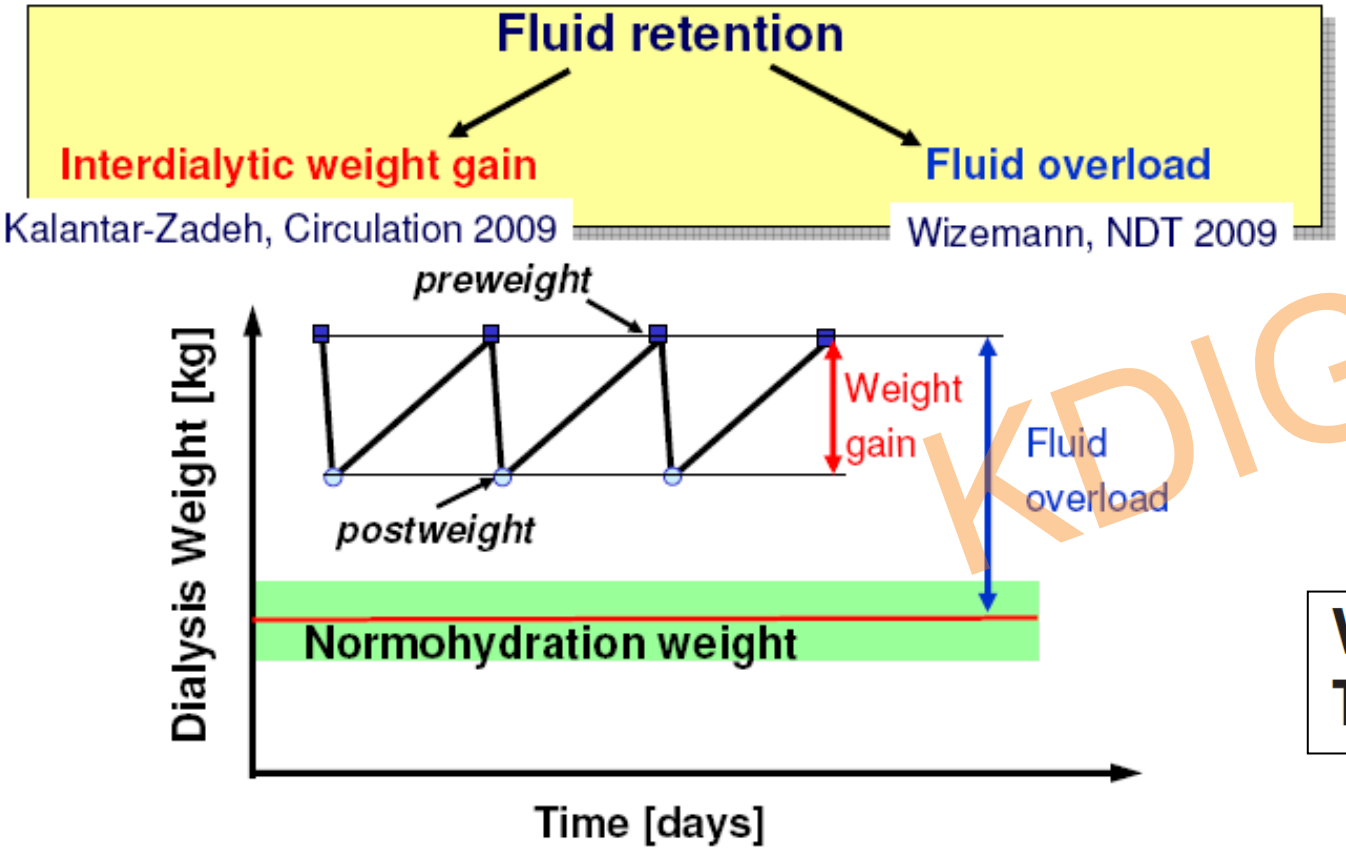
1. ***FluidWise Most Vulnerable Patients (MVPs):***
   - Patients at high-risk for fluid-related hospitalization based on risk stratification (approximately 10% of our patients)
2. ***Transition of care (TOC) patients***: post-hospitalization or new patients
3. ***Patients Not Meeting FluidWise Metric Targets:***
   - Patients with frequent excessive interdialytic weight gain
   - Patients with frequent post weight above TW by ≥ 1 kg
   - Patients with frequent post weight below TW by ≥ 1 kg

[…] "the interest in fluid management in the United States has taken root in the last 5 years. The two largest United States dialysis providers recently implemented fluid management clinical programs. In 2013, DaVita launched FluidWise, […] In late 2016, Fresenius Medical Care, North America released the Fluid Management Dashboard, […] that identifies patients with postdialysis weights ≥1 kg above or below their prescribed target weight and patients with ultrafiltration rates >13 ml/h per 1 kg in >30% of recent treatments."

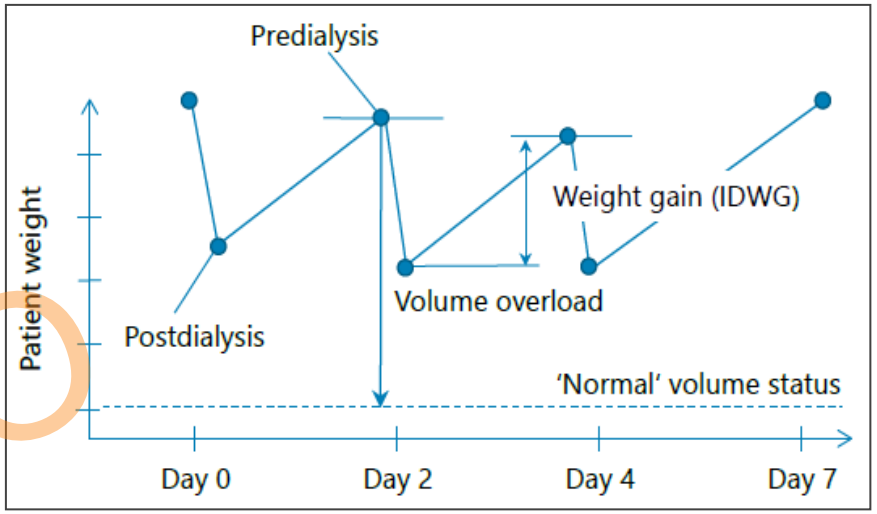
Flythe J, *J Am Soc Nephrol.* 2017 Aug;28(8):2260-2262

In the US, IDWG remains one of the most important parameters….

Strategy Of Volume Management: Fluid Overload And IDWG Are Not The Same



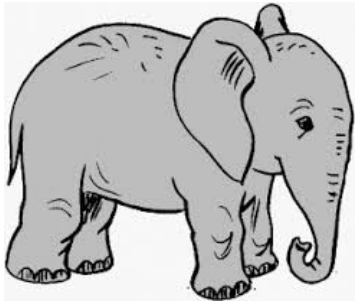
Interdialytic weight gain and fluid overload are two different measures.



Hecking M et al., *Am J Nephrol*. 2013;38(1):78-90

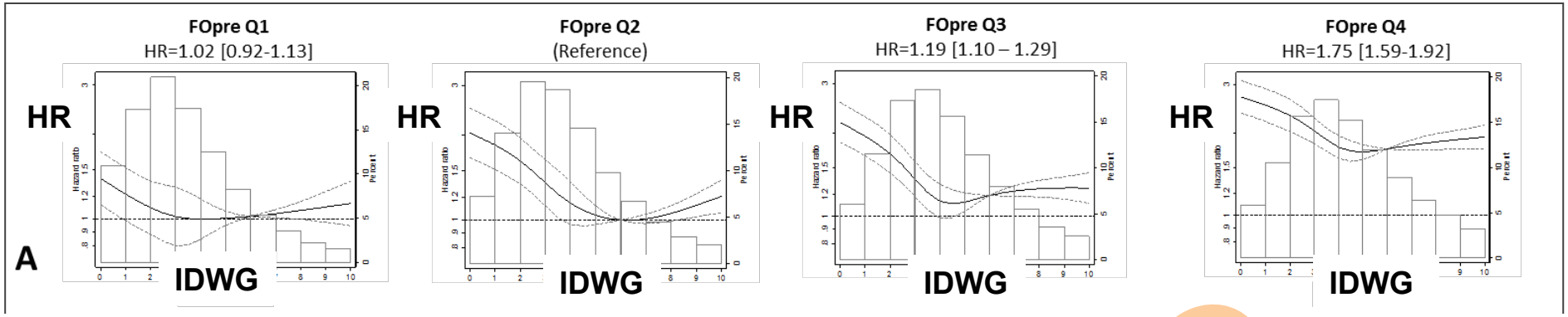
Volume Overload in Dialysis: The Elephant in the Room, No One Can See

Agarwal, R, *Am J Nephrol*. 2013;38(1):75-77



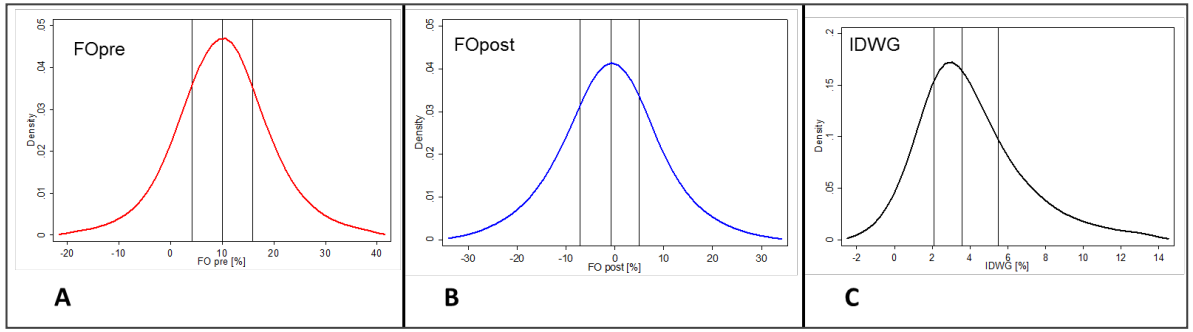
Courtesy Volker Wizemann: Heidelberger Dialyseseminar 2010

Strategic Volume Management: FO Versus IDWG

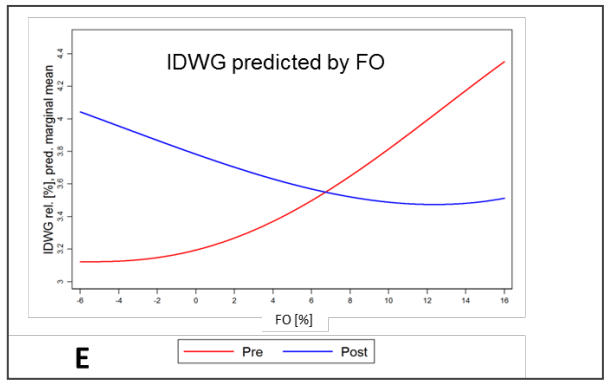


Principal Message: Greater FO and smaller IDWG predict mortality…

Dehydrated Patients may drink the most.



Cubic spline models estimating multivariate adjusted hazard ratios relative to the IDWG concentration in the second FO quartile (IDWG=0.06). FO quartiles were calculated based on longitudinal means over all measures of a patient during the follow-up. Hazards ratios for IDWG in FO quartiles 1, 3 and 4 were multiplied by the marginal hazard ratios of the FO quartile relative to the second FO quartile



Hecking, M et al., *Nephrol Dial Transplant*. 2018 Oct 1;33(10):1832-1842.

Does Fluid Volume Assessment, Intradialytic Volume Management, Strategic Volume Management (Dialysis Planing) Improve Outcomes?

Fluid Volume Assessment (By Bioimpedance)

Study or Subgroup	Bioimpedance Mean	Bioimpedance SD	Bioimpedance Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
Huan-Sheng 2016	1.49	1.04	148	1.64	1.4	150	34.9%	-0.15 [-0.43, 0.13]
Hur 2013	0.87	0.88	64	1.41	1.46	62	24.3%	-0.54 [-0.96, -0.12]
Luo 2011	1.72	1.51	78	2.52	1.83	82	19.0%	-0.80 [-1.32, -0.28]
Ponce 2014	2.92	1.47	101	3.36	1.75	88	21.8%	-0.44 [-0.90, 0.02]
Total (95% CI)			**391**			**382**	**100.0%**	**-0.43 [-0.71, -0.15]**

Heterogeneity: Tau² = 0.04; Chi² = 5.72, df = 3 (P = 0.13); I² = 48%
Test for overall effect: Z = 2.99 (P = 0.003)

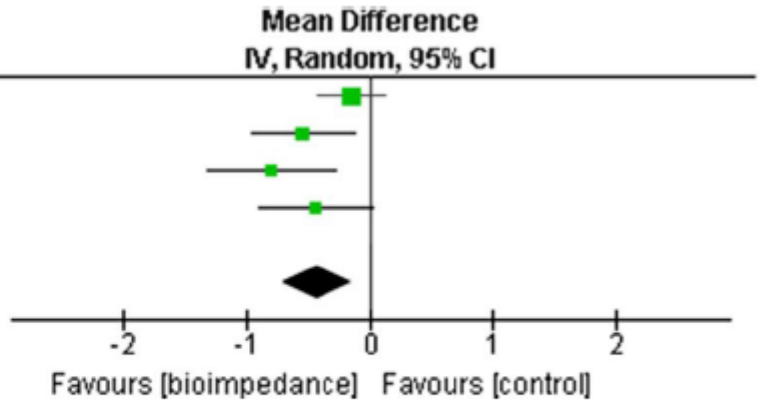


Fig. 4 Forest plot for change in overhydration (L)

Study or Subgroup	Bioimpedance Mean	Bioimpedance SD	Bioimpedance Total	Control Mean	Control SD	Control Total	Weight	Mean Difference IV, Random, 95% CI
Hur 2013	8.1	2.3	64	8.3	1.62	62	51.0%	-0.20 [-0.89, 0.49]
Onofriescu 2014	6.68	1.89	62	8.88	3.23	69	49.0%	-2.20 [-3.10, -1.30]
Total (95% CI)			**126**			**131**	**100.0%**	**-1.18 [-3.14, 0.78]**

Heterogeneity: Tau² = 1.83; Chi² = 11.98, df = 1 (P = 0.0005); I² = 92%
Test for overall effect: Z = 1.18 (P = 0.24)

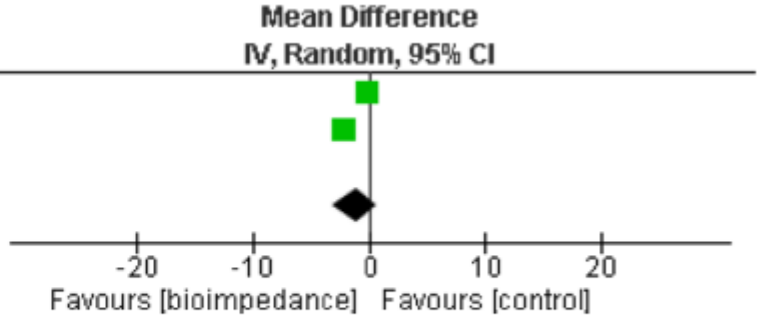


Fig. 7 Forest plot the effect on arterial stiffness (pulse wave velocity in m/s)

Covic A et al., *Int Urol Nephrol.* 2017 Dec;49(12): 2231-2245

Fluid Volume Assessment (By Bioimpedance)

Study or Subgroup	Bioimpedance Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Darlan 2010	135	19.4	34	141	23.3	36	5.1%	-6.00 [-16.02, 4.02]
Huan-Sheng 2016	136	23	148	136	22	150	19.7%	0.00 [-5.11, 5.11]
Hur 2013	120	19	64	125	19	62	11.7%	-5.00 [-11.64, 1.64]
Luo 2011	132.9	19.47	78	139.07	22.4	82	12.2%	-6.17 [-12.66, 0.32]
Onofriescu 2014	138.9	14.7	62	140.5	11.4	69	25.0%	-1.60 [-6.14, 2.94]
Ponce 2014	134.6	27.3	101	136.5	24.7	88	9.4%	-1.90 [-9.31, 5.51]
Tan 2016	130	21	39	135	18.4	36	6.5%	-5.00 [-13.92, 3.92]
Tan 2016	136	20	40	140	20	54	7.7%	-4.00 [-12.18, 4.18]
Tan 2016	128	26	29	123	27	25	2.6%	5.00 [-9.20, 19.20]
Total (95% CI)			**595**			**602**	**100.0%**	**-2.73 [-5.00, -0.46]**

Heterogeneity: Tau² = 0.00; Chi² = 4.80, df = 8 (P = 0.78); I² = 0%
Test for overall effect: Z = 2.36 (P = 0.02)

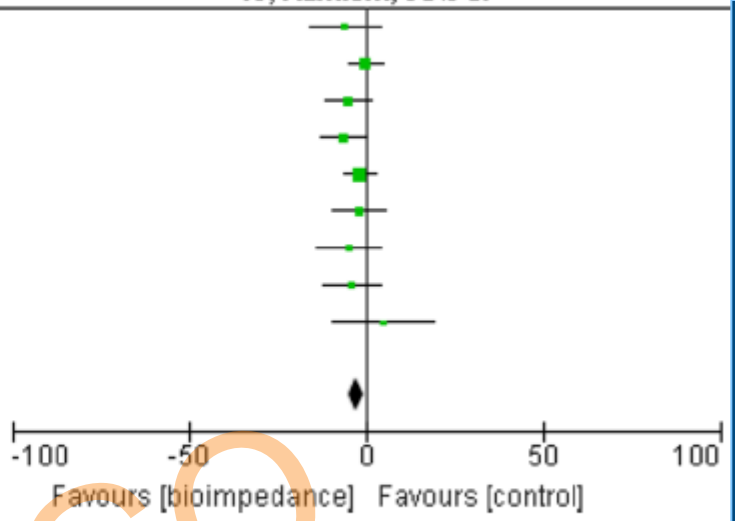


Fig. 6 Forest plot for systolic blood pressure control

Study or Subgroup	[Bioimpedance] Events	Total	[Control] Events	Total	Weight	Risk Ratio M-H, Random, 95% CI
Darlan 2010	1	34	2	36	4.0%	0.53 [0.05, 5.57]
Huan-Sheng 2016	6	148	7	150	19.5%	0.87 [0.30, 2.52]
Hur 2013	2	78	4	78	8.0%	0.50 [0.09, 2.65]
Onofriescu 2014	1	62	8	69	5.3%	0.14 [0.02, 1.08]
Ponce 2014	12	101	8	88	30.8%	1.31 [0.56, 3.05]
Tan 2016	10	149	11	159	32.4%	0.97 [0.42, 2.22]
Total (95% CI)		**572**		**580**	**100.0%**	**0.87 [0.54, 1.39]**
Total events	32		40			

Heterogeneity: Tau² = 0.00; Chi² = 4.75, df = 5 (P = 0.45); I² = 0%
Test for overall effect: Z = 0.58 (P = 0.56)

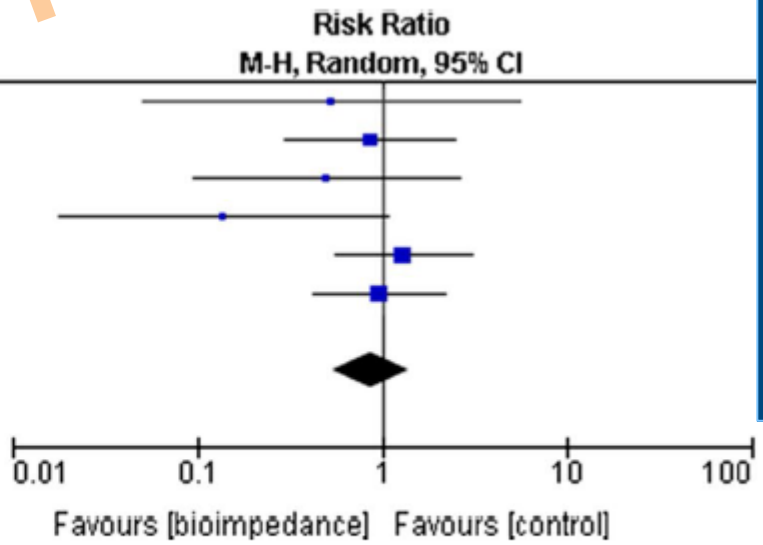


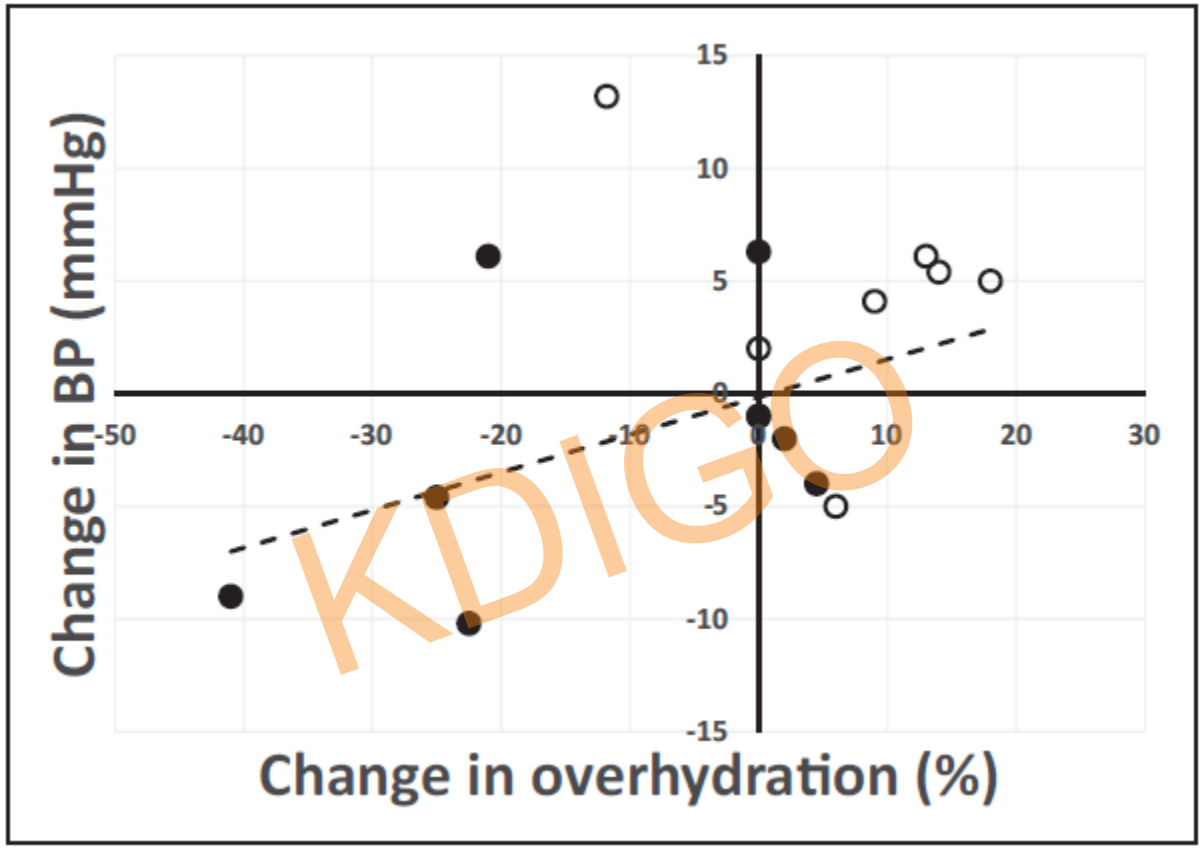
Fig. 3 Forest plot for all-cause mortality

[…] "BIA-based interventions for correction of overhydration have little to no effect on all-cause mortality, whereas BIA improved systolic blood pressure control. Our results should be interpreted with caution as the size and power of the included studies are low. Further studies, larger or with a longer follow-up period, should be performed" […]

Covic A et al., *Int Urol Nephrol.* 2017 Dec;49(12):2231-2245

Fluid Volume Assessment (By Bioimpedance)

Recent findings
Eight trials (published 2010–2018) and two meta-analyses (2017) are reviewed.



Summary
The usefulness of bioimpedance spectroscopy in guiding fluid management in dialysis patients is not yet clear. Bioimpedance can drive clinical decisions that lead to significant changes in fluid status but the best way to apply this in clinical practice requires further studies.

Tabinor M & Davies S, *Curr Opin Nephrol Hypertens.* 2018 Nov;27(6):406-412

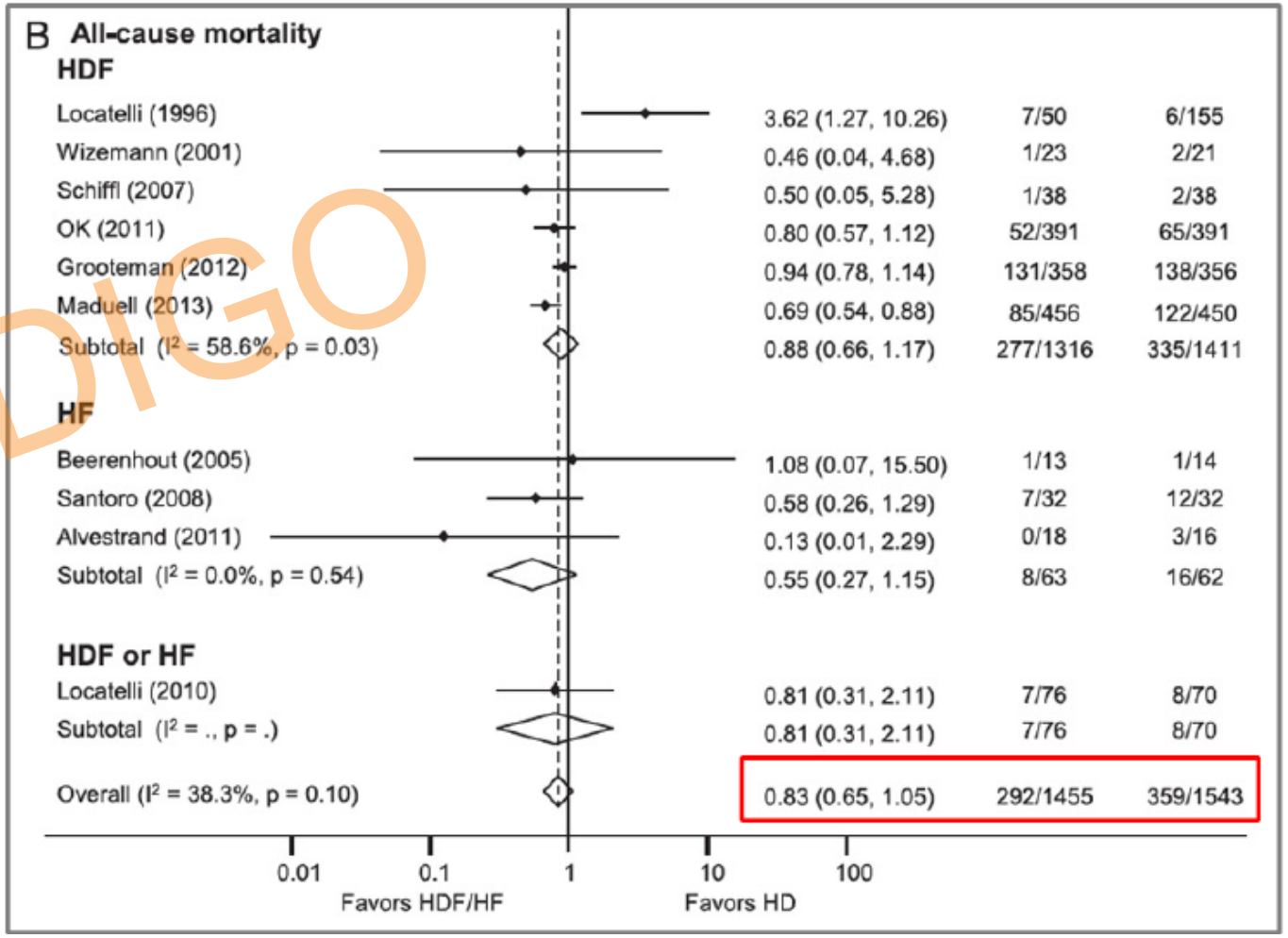
Does Fluid Volume Assessment, Intradialytic Volume Management, Strategic Volume Management (Dialysis Planing) Improve Outcomes?

Intradialytic Volume Management: HemoFiltration / HemoDiaFiltration

Outcomes

- Mortality
- Hospitalizations
- Intradialytic Hypotension
- Biochemical Markers
- Body Mass Index

"The potential benefits of convective modalities over standard HD for cardiovascular outcomes and mortality remain unproved. Further high-quality randomized trials are needed to define the impact of these modalities on clinically important outcomes."



Wang AY et al., *Am J Kidney Dis.* 2014 Jun;63(6):968-78

Does Fluid Volume Assessment, Intradialytic Volume Management, Strategic Volume Management (Dialysis Planing) Improve Outcomes?

Intradialytic Volume Management: HemoFiltration / HemoDiaFiltration

Outcomes

- Mortality
- Hospitalizations
- Intradialytic Hypotension
- Biochemical Markers
- Body Mass Index

Santoro A et al., *Am J Kidney Dis.* 2008 Sep;52(3):507-18	Hemofiltration better
Locatelli F et al., *J Am Soc Nephrol.* 2010 Oct;21(10):1798-807	Hemofiltration better Hemodiafiltration better
Vilar E et al., *Clin J Am Soc Nephrol.* 2009 Dec;4(12):1944-53	Hemodiafiltration better
Maduell F et al., *J Am Soc Nephrol.* 2013 Feb;24(3):487-97	Hemodiafiltration better
Schiffl H et al., *Int Urol Nephrol.* 2013 Oct;45(5):1389-96	Hemodiafiltration better
Ok E et al., *Nephrol Dial Transplant.* 2013 Jan;28(1):192-202	No difference

Table 2. Randomized clinical studies evaluating the role of HDF on dialysis tolerance

Reference	Design	Treatments	Patients	Sample size	Relative risk reduction, %	p value
Locatelli et al. [8], 1996	randomized, prospective	Cuprophane HD Low-flux HD High-flux HD HDF	132 147 51 50	380		n.s.
Altieri et al. [30], 2004	randomized, crossover, prospective	HF HDF		39	54.5	0.017
Schiffl [31], 2007	randomized, crossover, prospective, secondary analysis	High-flux HD HDF	76 76	152	63.6	<0.05
Locatelli et al. [21], 2010	randomized, prospective	Low-flux HD Online HF Online HDF	70 36 40	146	50	0.001
Maduell et al. [22], 2013	randomized, prospective, secondary analysis	High-flux HD Online HDF	450 456	906	28	<0.001

Grooteman MPC et al., *J Am Soc Nephrol.* 2012 Jun;23(6):1087-96 **["CONTRAST"]**

IDH not analyzed

Locatell F, *Blood Purif.* 2015; 40 Suppl 1:24-9

Does Fluid Volume Assessment, Intradialytic Volume Management, Strategic Volume Management (Dialysis Planing) Improve Outcomes?

Intradialytic Volume Management: Cooling/"Thermoneutrality" Against IDH

Review: Systematic review of the effects of adjusting thermal balance during haemodialysis
Comparison: 01 IDH
Outcome: 03 IDH rate

Study or sub-category	Rate ratio (random) 95% CI	Weight %	Rate ratio (random) 95% CI	Year	Quality
01 fixed temp reduction					
Jost 1993		10.19	35.71 [32.91, 38.51]	1993	A
Ayoub 2004		10.08	13.69 [10.83, 16.55]	2004	B
Cruz 1999		13.74	4.87 [4.61, 5.13]	1999	B
Van Der Sande 1999		11.76	2.00 [0.04, 3.96]	1999	B
Dheenan 2001		13.53	2.50 [1.85, 3.15]	2001	C
Fine 1996		13.72	2.24 [1.93, 2.55]	1996	C
Subtotal (95% CI)		73.02	9.53 [6.69, 12.36]		
Test for heterogeneity: Chi² = 720.30, df = 5 (P < 0.00001), I² = 99.3%					
Test for overall effect: Z = 6.59 (P < 0.00001)					
02 BTM					
Maggiore 2002		13.77	2.00 [1.86, 2.14]	2002	B
Kaufman 1998		13.21	1.86 [0.88, 2.84]	1998	C
Subtotal (95% CI)		26.98	2.00 [1.86, 2.14]		
Test for heterogeneity: Chi² = 0.08, df = 1 (P = 0.78), I² = 0%					
Test for overall effect: Z = 27.65 (P < 0.00001)					
Total (95% CI)		100.00	7.09 [5.34, 8.85]		
Test for heterogeneity: Chi² = 951.06, df = 7 (P < 0.00001), I² = 99.3%					
Test for overall effect: Z = 7.92 (P < 0.00001)					

-100 -50 0 50 100
Favours std dialysis Favours cool temp

(B)

Review: Systematic review of the effects of adjusting thermal balance during haemodialysis
Comparison: 01 IDH
Outcome: 02 IDH rate

Study or sub-category	IDH rate ratio (random) 95% CI	Weight %	IDH rate ratio (random) 95% CI	Year	Quality
01 fixed temp reduction					
Cruz 1999		18.01	4.87 [4.60, 5.14]	1999	B
Van Der Sande 1999		12.09	2.00 [0.04, 3.96]	1999	B
Dheenan 2001		17.66	2.50 [2.03, 2.97]	2001	C
Fine 1996		17.95	2.24 [1.93, 2.55]	1996	C
Subtotal (95% CI)		65.71	2.97 [1.33, 4.61]		
Test for heterogeneity: Chi² = 177.06, df = 3 (P < 0.00001), I² = 98.3%					
Test for overall effect: Z = 3.54 (P = 0.0004)					
02 BTM					
Maggiore 2002		18.14	2.00 [1.86, 2.14]	2002	B
Kaufman 1998		16.15	1.86 [0.88, 2.84]	1998	C
Subtotal (95% CI)		34.29	2.00 [1.86, 2.14]		
Test for heterogeneity: Chi² = 0.08, df = 1 (P = 0.78), I² = 0%					
Test for overall effect: Z = 27.65 (P < 0.00001)					
Total (95% CI)		100.00	2.63 [1.45, 3.80]		
Test for heterogeneity: Chi² = 337.38, df = 5 (P < 0.00001), I² = 98.5%					
Test for overall effect: Z = 4.37 (P < 0.0001)					

-10 -5 0 5 10
Favours standard HD Favours cool temp

Selby NM & McIntyre CW,
Nephrol Dial Transplant. 2006 Jul;21(7):1883-98

Fixed Temperature Reduction and Body Temperature Monitor better

Does Fluid Volume Assessment, Intradialytic Volume Management, Strategic Volume Management (Dialysis Planing) Improve Outcomes?

Intradialytic Volume Management: Iso-UF Against IDH

No Meta-Analyses Identified

Isolated Ultrafiltration better
(only older studies)

Does Fluid Volume Assessment, Intradialytic Volume Management, Strategic Volume Management (Dialysis Planing) Improve Outcomes?

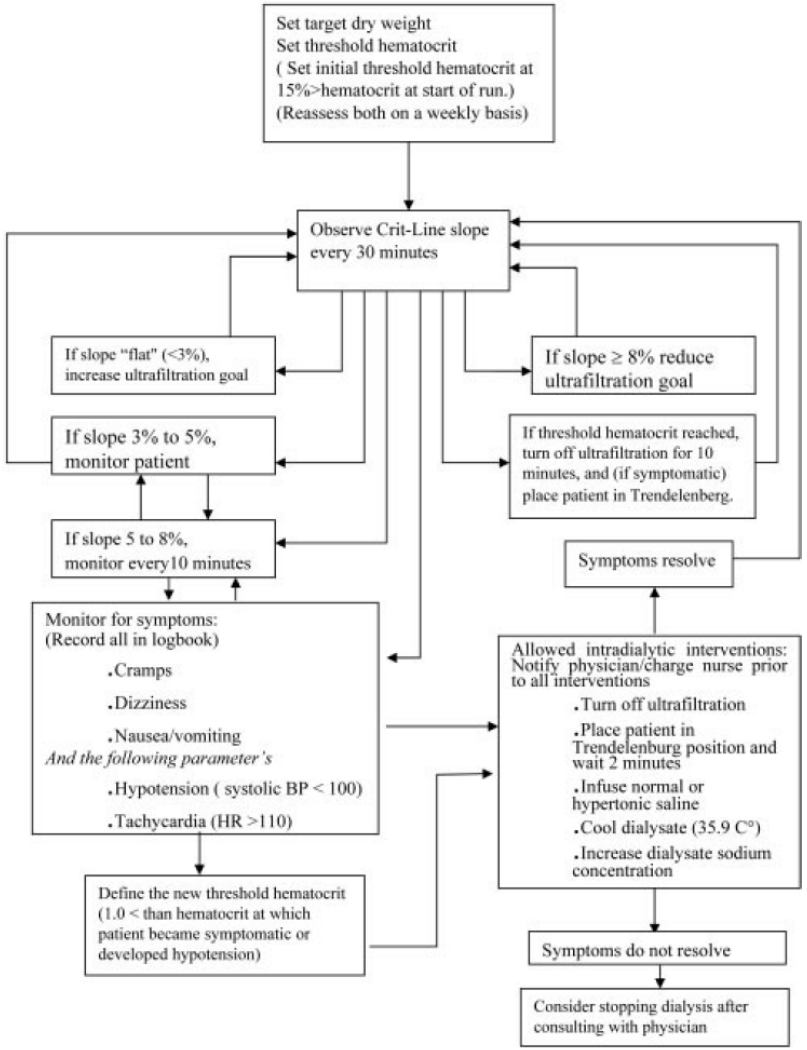
Sodium Concentration in the Dialysate – Sodium Modelling

I am "not allowed" to comment, and there certainly is no time

Be Aware of Bias(!!!!) and Inadequate Na-Delivery when Interpreting any Study

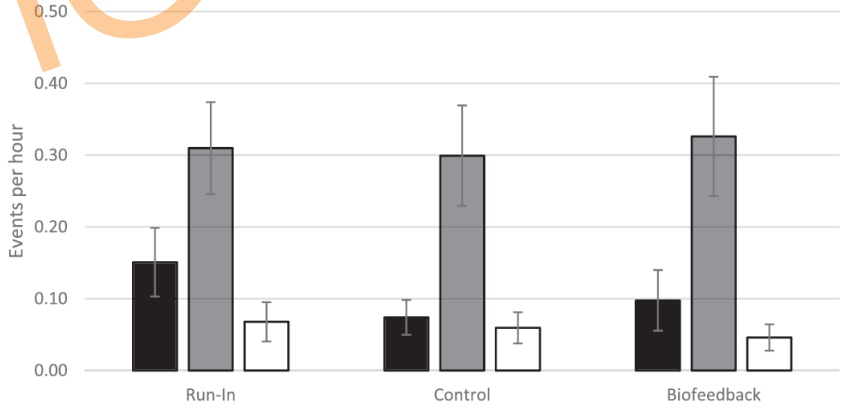
Does Fluid Volume Assessment, Intradialytic Volume Management, Strategic Volume Management (Dialysis Planing) Improve Outcomes?

Relative Blood Volume-Controlled Feedback of the Ultrafiltration Rate



"The adjusted risk ratio for non–access-related and access-related hospitalization was 1.61 (95% confidence interval 1.15 to 2.25; P 0.01) and 1.52 (95% confidence interval 1.02 to 2.28; P 0.04) for the Crit-Line monitoring group. Mortality was 8.7% in the Crit-Line monitoring group and 3.3% in the conventional group (P 0.021)..."

Reddan DM et al., *J Am Soc Nephrol.* 2005 Jul;16(7):2162-9.



Leung KCW, *Clin J Am Soc Nephrol.* 2017 Nov 7;12(11):1831-1840

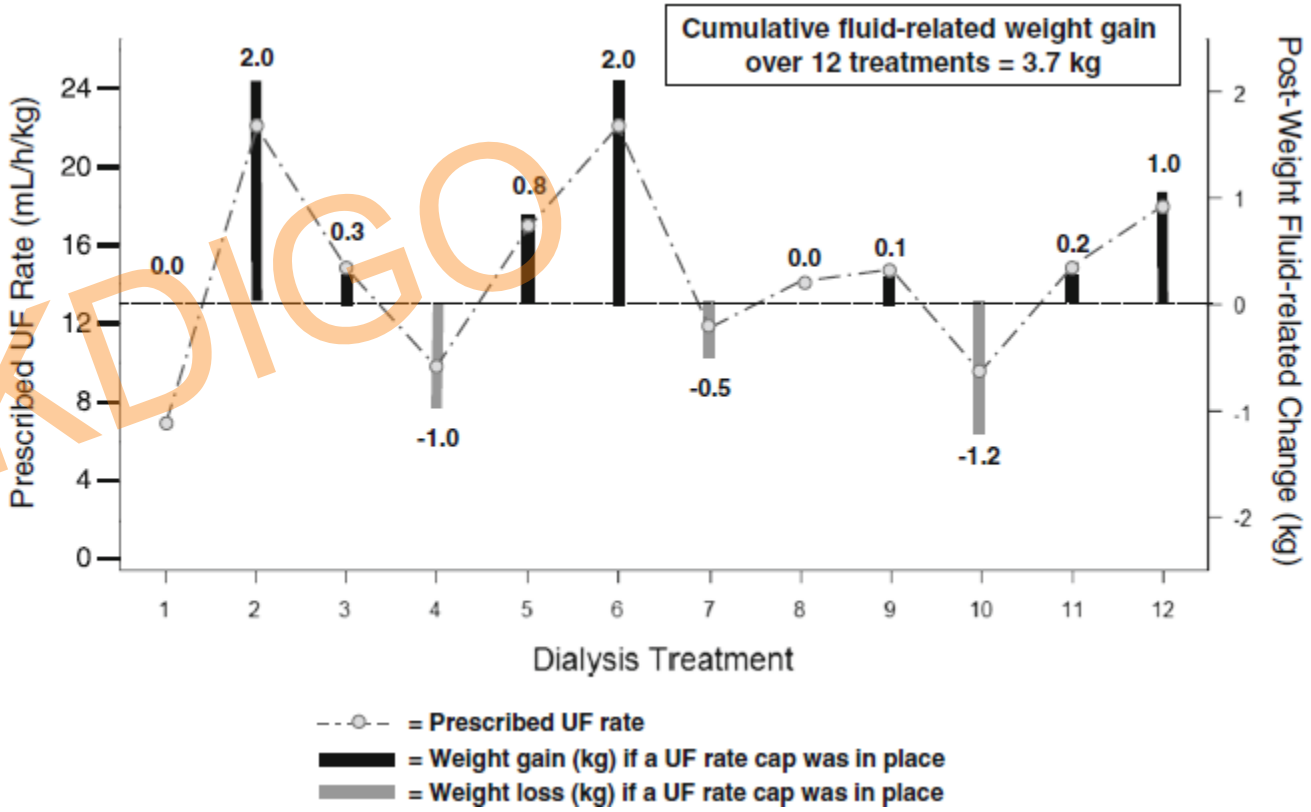
Leung et al.: No Difference
Meta-Analysis (Nesrallah et al., NDT 2013) not considered because Sodium Condictivity was also adjusted

Does Fluid Volume Assessment, Intradialytic Volume Management, Strategic Volume Management (Dialysis Planing) Improve Outcomes?

Strategic Volume Management (Dialysis Planing)

We computed the cumulative, theoretical 1-month fluid-related weight gain that would occur if UF rates were capped at 13 mL/h/kg without concurrent TT extension or IDWG reduction.

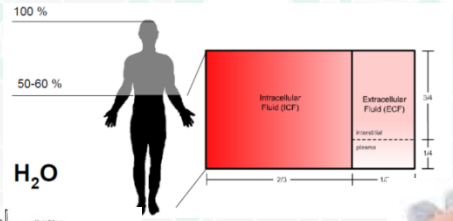
"Implementation of a maximum UF rate threshold without adequate attention to extracellular volume status may lead to fluid-related weight gain.."

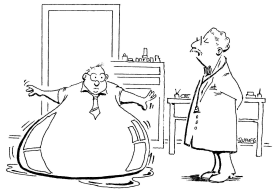


Flythe J et al., *BMC Nephrol.* 2017 Jun 2;18(1):185

Summary

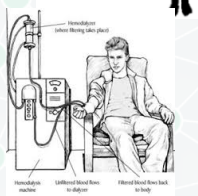
"Controversis Conference"… 1st Controversy May Be Blood Pressure: Not Necessarily Higher in Fluid Overloaded Patients





Technologies

(1) For Volume [Dry Weight] Assessment
(2) For Volume Management
(3) For Strategic Dialysis Planing



Associations Of (1) (2) (3) with Outcomes, Prospective Mortality Benefit Unclear

- Pedal Edema
- Chest X-ray
- Inferior Vena Cava Diameter
- Biochemical Markers
- Lung Comets
- (Diagnostic) Relative Blood Volume Monitoring
- Dual-energy X-ray absorptiometry (=DXA)

- Magnetic Resonance Imaging (MRI)
- Echocardiography
- Pulmonary Artery Pressure
- Pulse Pressure
- Stroke Volume Variation
- Leg Raising Test
- Blood Pressure Measurement
- Bioimpedance (spectroscopy)

- Hemofiltration/Hemo-diafiltration
- Cooling
- ~~Sodium Profiling~~
- Relative Blood Volume-Controlled Feedback of the Ultrafiltration Rate
- Absolute Blood Volume
- Isolated Ultrafiltration

- Session Length
- UF Rate
- Target Weight Achievement

- Differentiating between IDWG and Chronic Fluid Overload through [1] objective TW Assessement

Time For…

Turning the Tide: Improving Fluid Management in Dialysis through Technology

Flythe J, *J Am Soc Nephrol.* 2017 Aug; 28(8):2260-2262