Dry Weight

METHODS OF MEASURING DRY WEIGHT

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Dry Weight: definition

- The weight at which the dialysis patient has ***neither edema nor hypertension*** with no BP medication
- Normally achieved with ultrafiltration ***until*** hypotensive crisis
- Iatrogenic shock:
  - Nausea
  - intradialytic hypotension
  - cramps during dialysis

Thomson GE, Waterhouse K, McDonald HP Jr, Friedman EA: Hemodialysis for for chronic renal failure. Clinical observations. Arch Intern Med 1967;120:153-167

Dry Weight

- Dry weight is achieved when the pt is in shock
  - Clinical definition: “challange”

- This is very uncomfortable
- There is always a risk of adverse outcome

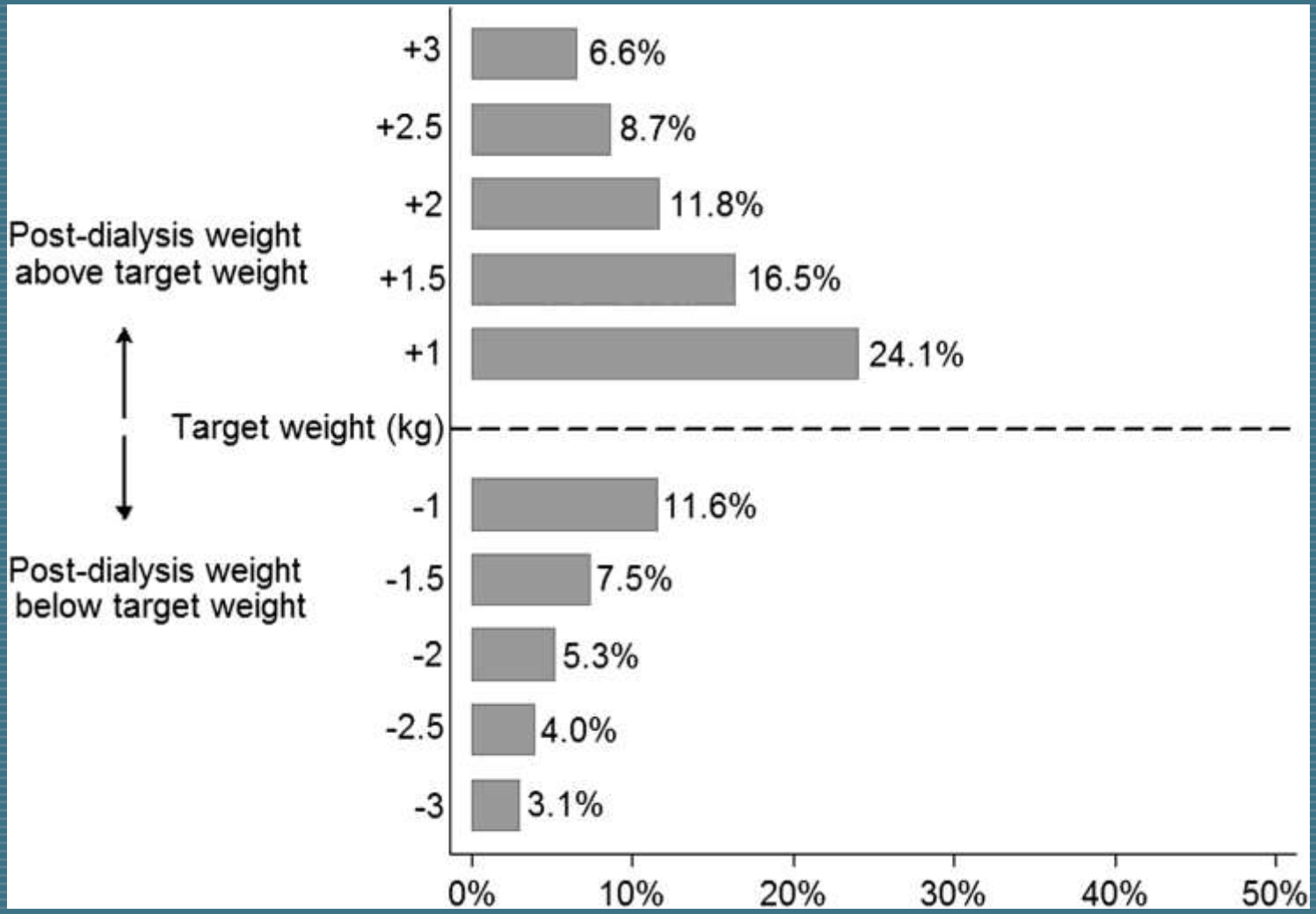
- …there must be a better way…

The Ideal Dry Weight

- (1) shortest post-dialysis recovery time;
- (2) least intradialytic hypotension;
- (3) longest patient survival;
- (4) fewest cardiovascular and cerebrovascular events and hospitalizations
  - Risk of myocardial stunning, risk of seizures
- (5) fewest hypovolemia-related access thromboses;
- and (6) fewest post-dialysis falls

Agarwal R, Weir MR: Dry-weight: A concept revisited in an effort to avoid medication-directed approaches for blood pressure control in hemodialysis patients. Clin J Am Soc Nephrol 5: 1255–1260, 2010

Frequency of target weight miss by varying thresholds.



Jennifer E. Flythe et al. CJASN 2015;10:808-816

Intravascular volume assessment of Dry Weight

- In HD patients:
  - in a study of 22 patients
  - underwent a **right heart catheterization** at a time when clinical dry weight was thought to be adequate
    - --> only 6 had normal filling pressures

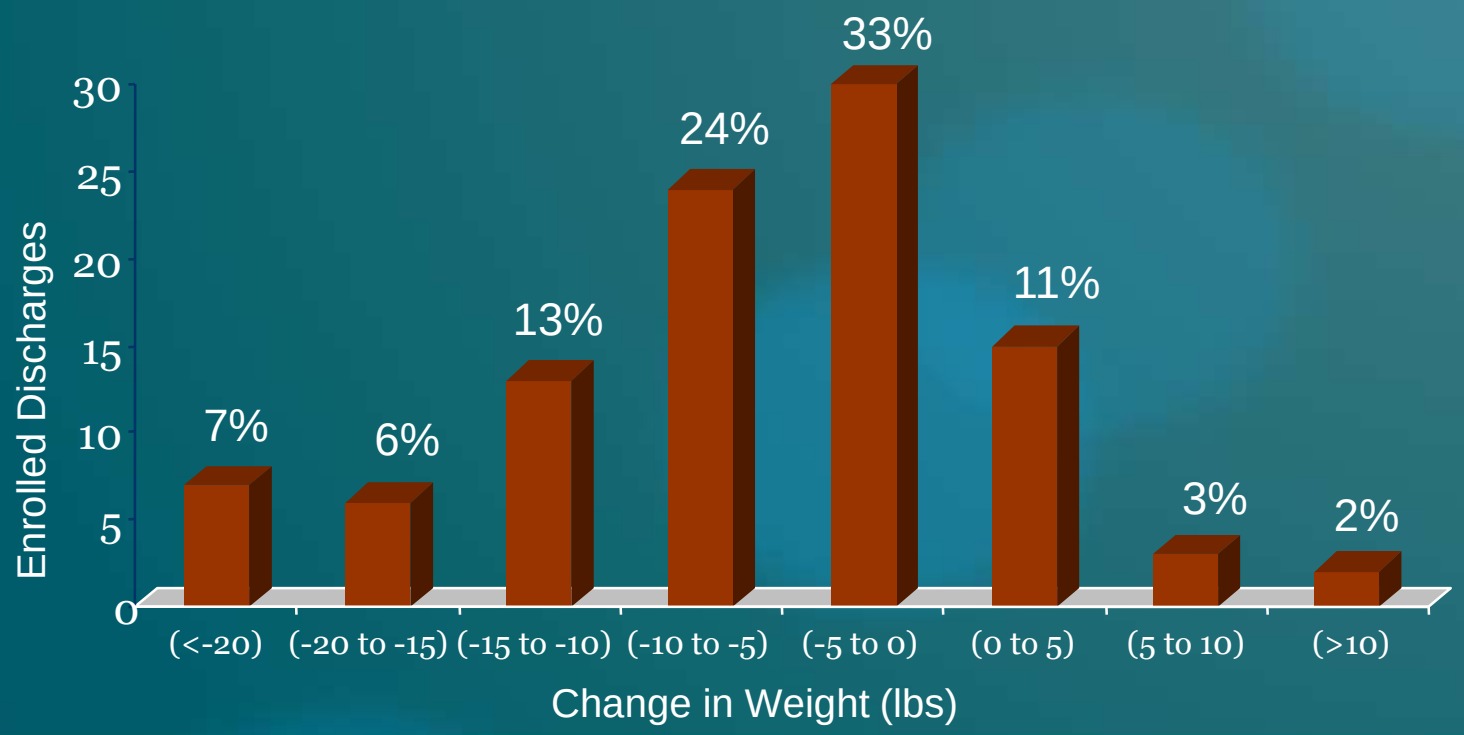
Cheriex EC, Leunissen KM, Janssen JH, Mooy JM, van Hooff JP: Echography of the inferior vena cava is a simple and reliable tool for estimation of "dry weight" in haemodialysis patients. *Nephrol Dial Transplant* 4:563–568, 1989

Lack of Weight Loss in Large Fraction of Patients Admitted for Acute Heart Failure

All Enrolled Discharges from October 2001 to January 2004

Change in weight was assessed in **51,013** patient episodes (at end:107 362)

Discharged Home (including home with additional and/or outpatient care)



Adhere

Adams et al. Am Heart J. 2005 Feb;149(2):209-16.

Specificity and Sensitivity in Diagnosing CHF

100 patients presenting to the ER with signs or symptoms of congestive heart failure (e.g., dyspnea, edema, weight gain)

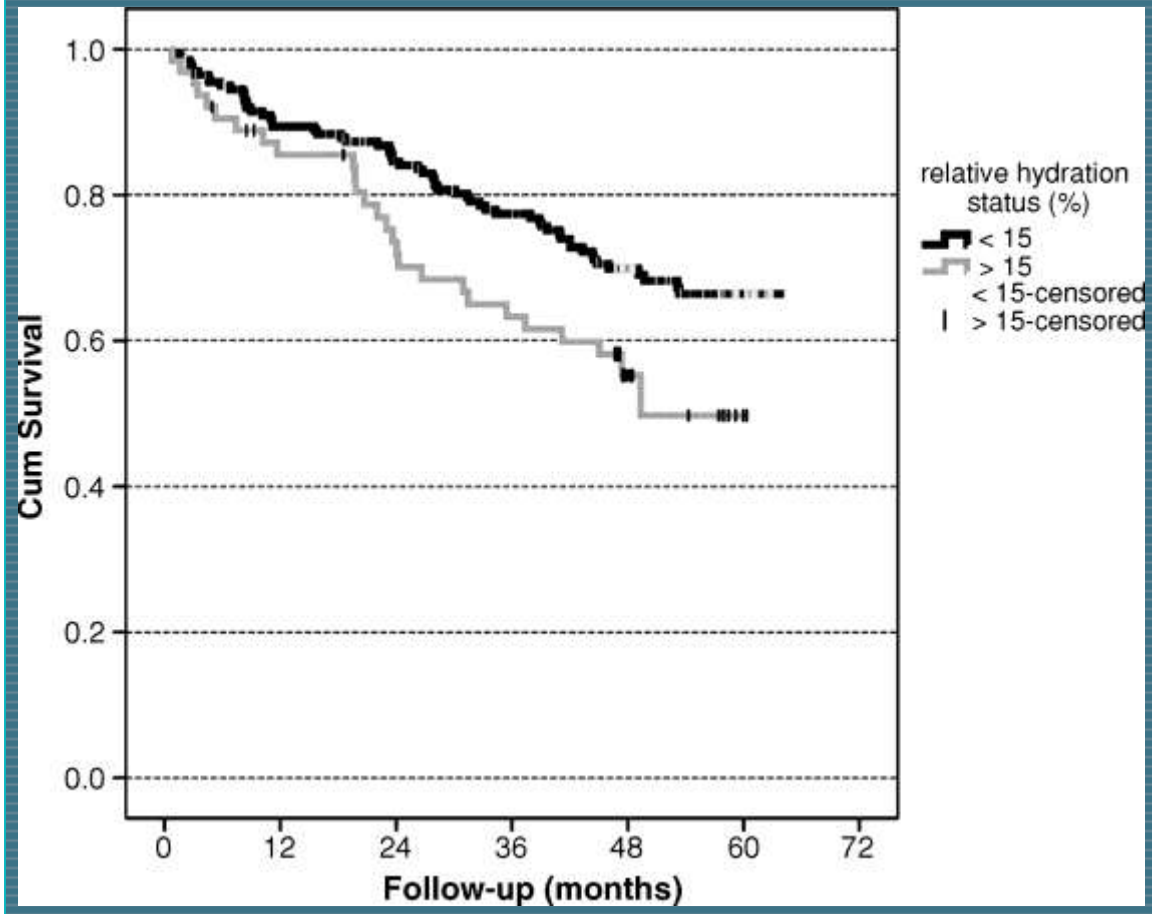
	Specificity	Sensitivity
Elevated Neck Veins	92%	34%
Third Heart Sound	90%	26%
Crackles in the Lungs	81%	57%
BNP (cutoff value of 100 pg/mL)	98%	100%

Dao and colleagues, 49th Annual Scientific Session of the American College of Cardiology

Risk of excessive fluid volume

- Increased mortality
- Hypertension
  - Polypharmacy
  - Inadequate BP control
- Congestive Heart Failure (CHF)

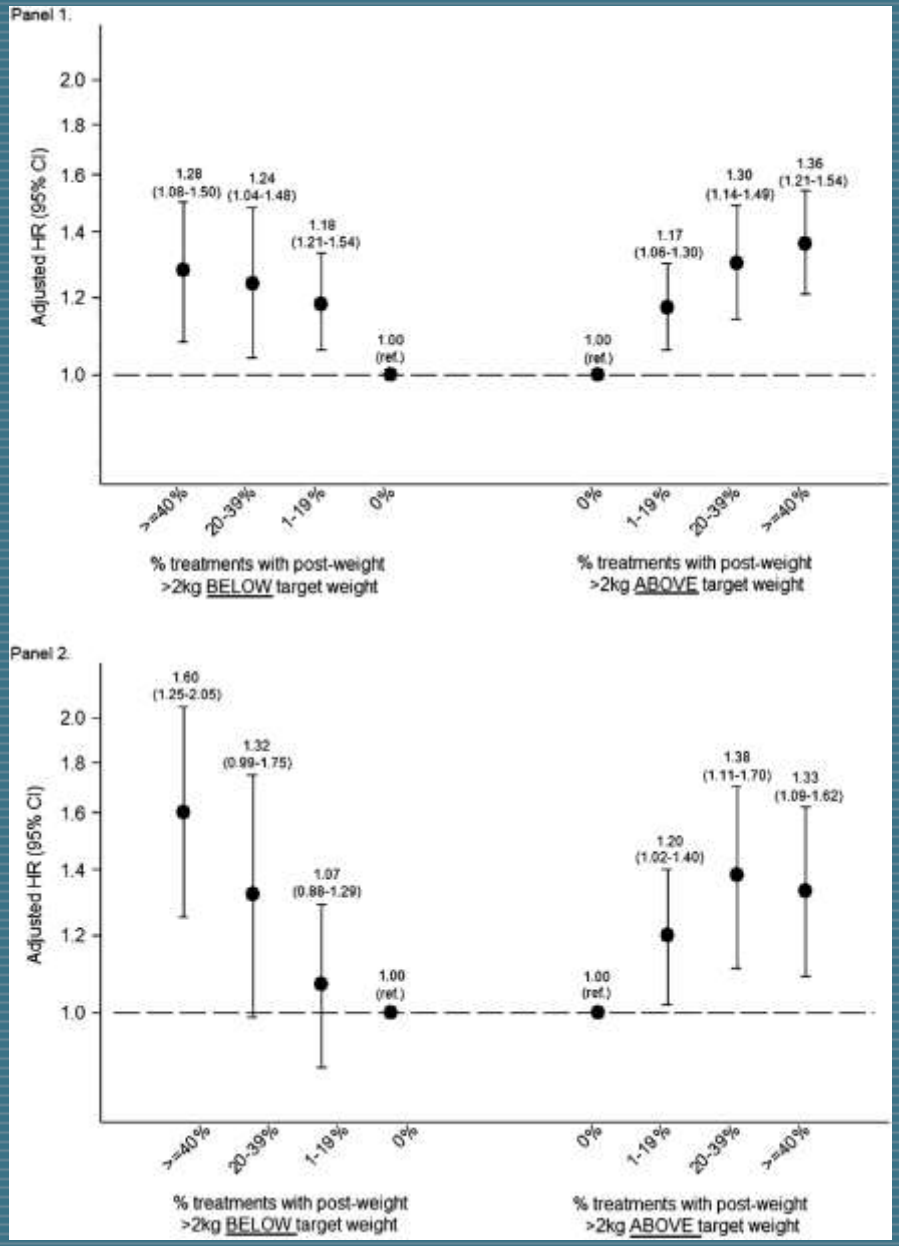
Relative Hydration Status (OH% >15%)



- Bioimpedence measurements
- Hyperhydration: 15% relative to the extracellular water (ECW), which represents an excess of ECW of 2.5 L

Wizemann, V. et al. Nephrol. Dial. Transplant. 2009 24:1574-1579; doi:10.1093/ndt/gfn707

NDT
Nephrology Dialysis Transplantation



Higher frequency of target weight misses (above and below) **was incrementally associated with greater mortality.**

Jennifer E. Flythe et al. CJASN 2015;10:808-816

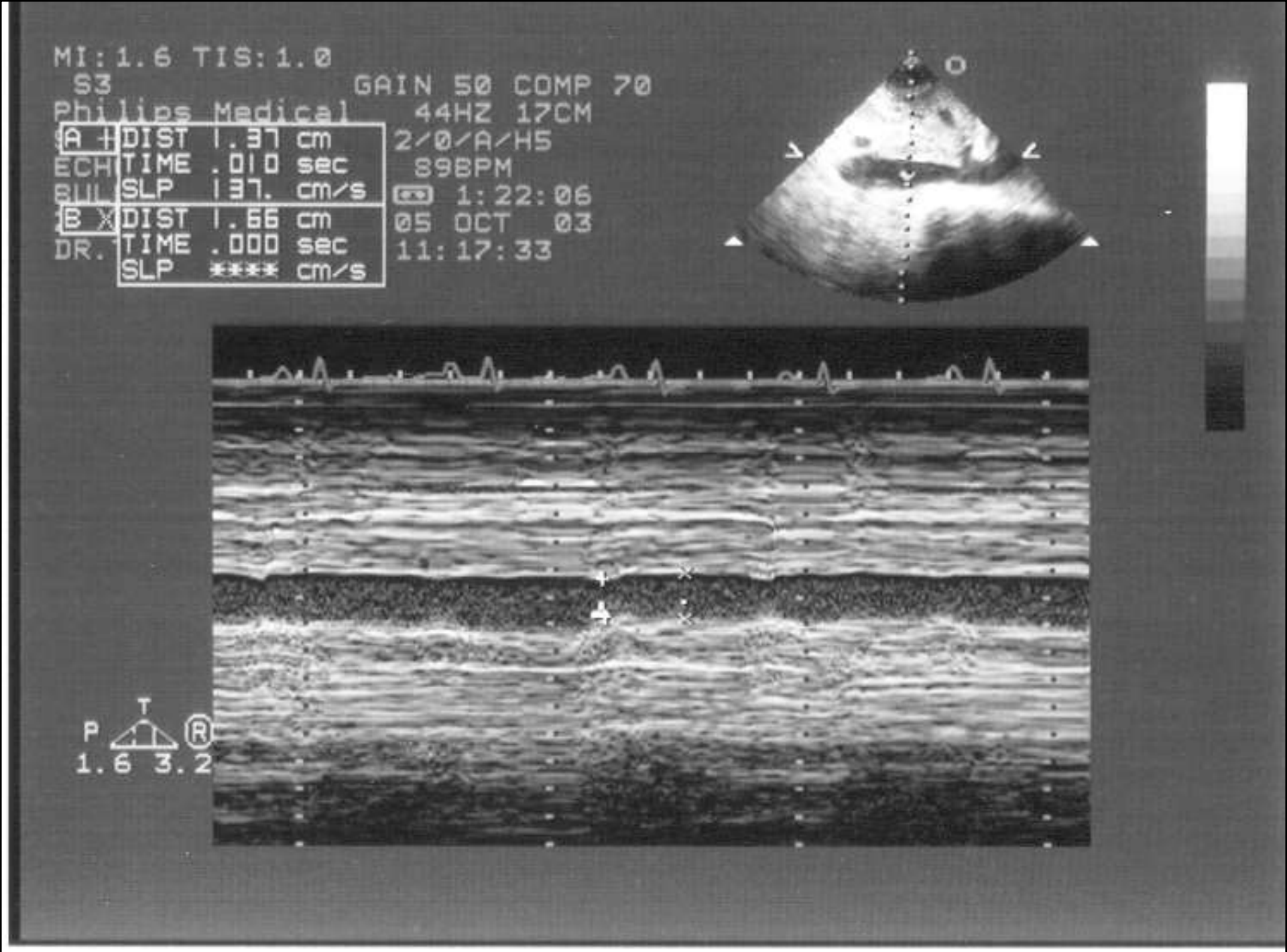
Risk of excessive ultrafiltration (going below dry weight)

- (1) increased risk of clotted fistula,
- (2) increased rate of loss of residual renal function,
- (3) complications related to intradialytic hypotension.
- (4) frequent episodes of malaise, weakness, increase risk of falls, episodes of intradialytic hypotension,
- (5) brain hypoperfusion, with subsequent white matter degeneration
  - Eldehni MT, McIntyre CW: Semin Dial 25: 253–256, 2012
- (6) gastrointestinal ischemia leading to endotoxin exposure is also a plausible clinical consequence of overaggressive ultrafiltration
  - McIntyre CW et al.: Clin J Am Soc Nephrol 6: 133–141, 2011

- Intradialytic hypotension, in addition to requiring more nursing interventions, can be complicated by cerebral hypoperfusion, seizures, myocardial dysfunction, and mesenteric ischemia.
  - KL Jablonski, M Chonchol April 2015, doi: 10.2215/?CJN.03110315 CJASN May 07, 2015 vol. 10 no. 5 729-731

Methods of fluid status measurements

- 2D Echocardiography
  - IVC measurement:
    - IVC/BSA ratio
    - IVC Collapse Index
  - Sphericity index
- Biomarkers:
  - BNP
  - NT-pro-BNP
- Bioimpedance
- Continuous Hematocrit monitoring
- Relative Blood Volume Monitoring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SLP **** cm/s
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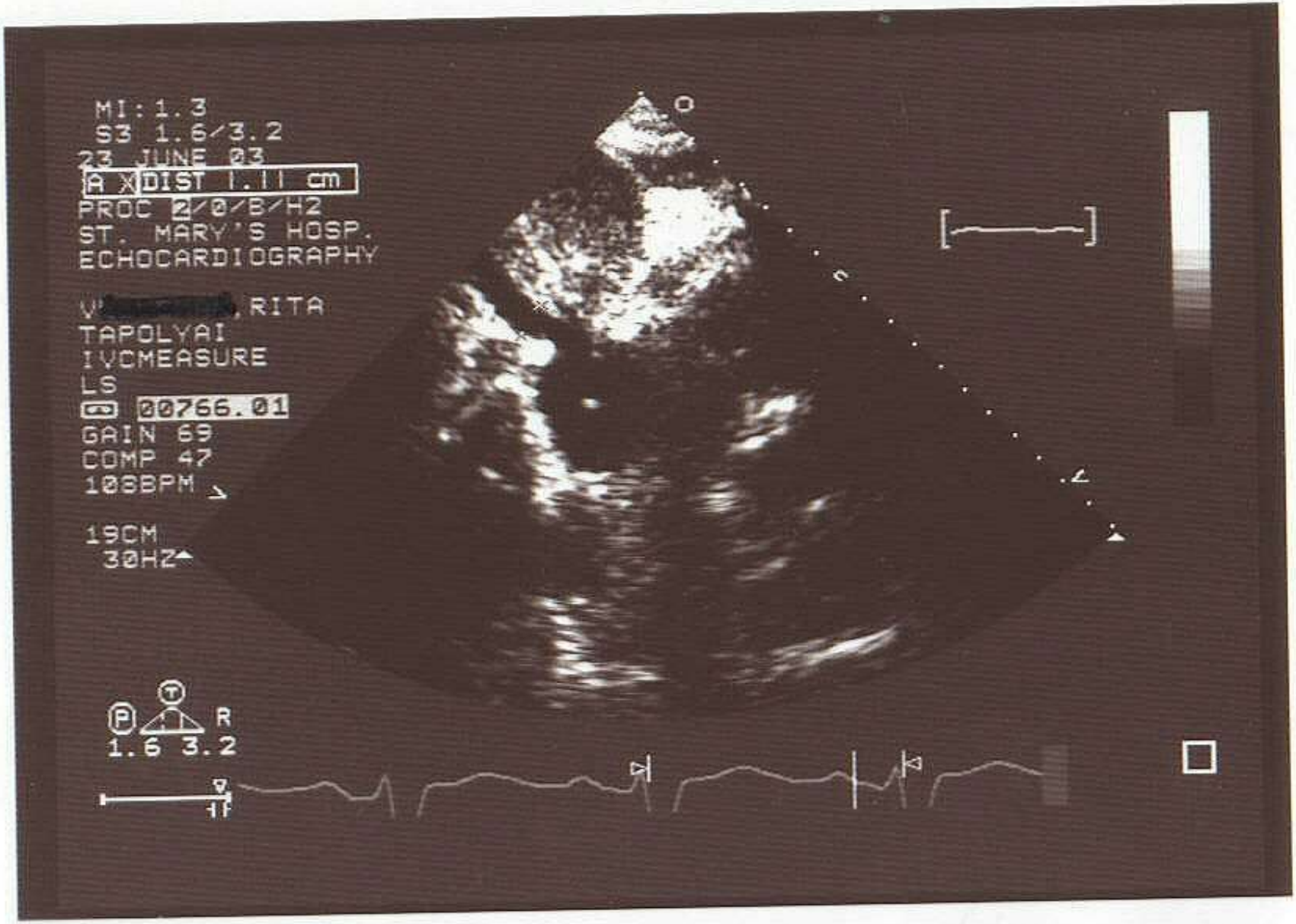
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108BPM
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Intravascular volume measurement: Echocardiogram

- Either by using cardiac **IVC Collapse Index**:

  CI = [(end expiratory IVC diameter–end inspiratory IVC diameter)/end expiratory IVC diameter]×100

- **Hypervolemia:** CI greater than **0.75**
  - i.e., the collapse of IVC diameter during inspiration was less than 25% of the baseline diameter during expiration

Cheriex EC et al *Nephrol Dial Transplant* 4:563–568, 1989

Intravascular volume measurement: Echocardiogram

- IVC/BSA ratio:
  - 8.0 - 11.5 mm/m²
  - Hypovolemia: **<8.0** mm/m²
    - Corresponds to right atrial pressure on right sided catheterization: 3.0 mmHg or less
  - Hypervolemia: **>11.5** mm/m²
    - Corresponds to right atrial pressure on right sided catheterization: 7.0 mmHg or more

Cheriex EC et al *Nephrol Dial Transplant* 4:563–568, 1989

Intravascular volume measurement: Echocardiogram

- IVC U/S measurement:
  - IVC diameter **can detect** clinically unapparent **volume depletion**[1]
  - interventions based on such measurements may improve hemodynamics[1]

- Nonlinnear regression analysis found[2] that *the **Collapse Index** strongly correlated with mean **right atrial pressure***
  - ***r*= 0.92**, $p < 0.001$ as assessed by right heart catheterization.

[1]Leunissen Kmet al. *Kidney Int* 43(suppl 41):S50–S56, **1993**
[2]Cheriex EC et al *Nephrol Dial Transplant* 4:563–568, **1989**

Intravascular volume measurement: Echocardiogram

- PROS:
  - Strong correlation with right heart catheterization, reflecting intravascular volume
    - Can assess both volume **depletion** and **overload**
  - Noninvasive
  - Valid measurement in non-dialysis patients as well

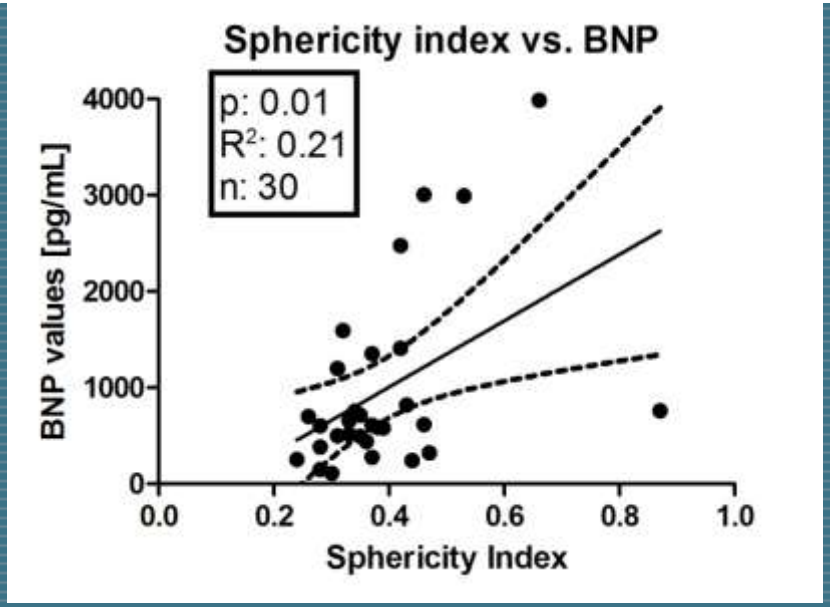
- CONS:
  - Best timing after HD not defined
  - Must train skilled technicians
  - Cost
  - Limited availability

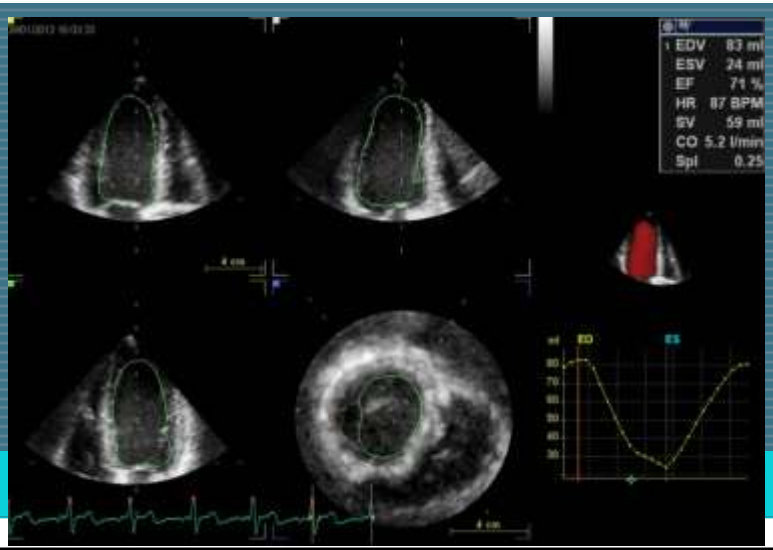
Intravascular volume measurement: Echocardiogram

- Sphericity index:
  - The rounder a heart is the more fluid it is distends it
  - The more elongated, the less fluid it holds

Sph.Index = EDV/(LAD^3 x pi)/6

A Kovács et al.; *J Am Soc Nephrol suppl SA-PO433 2013*





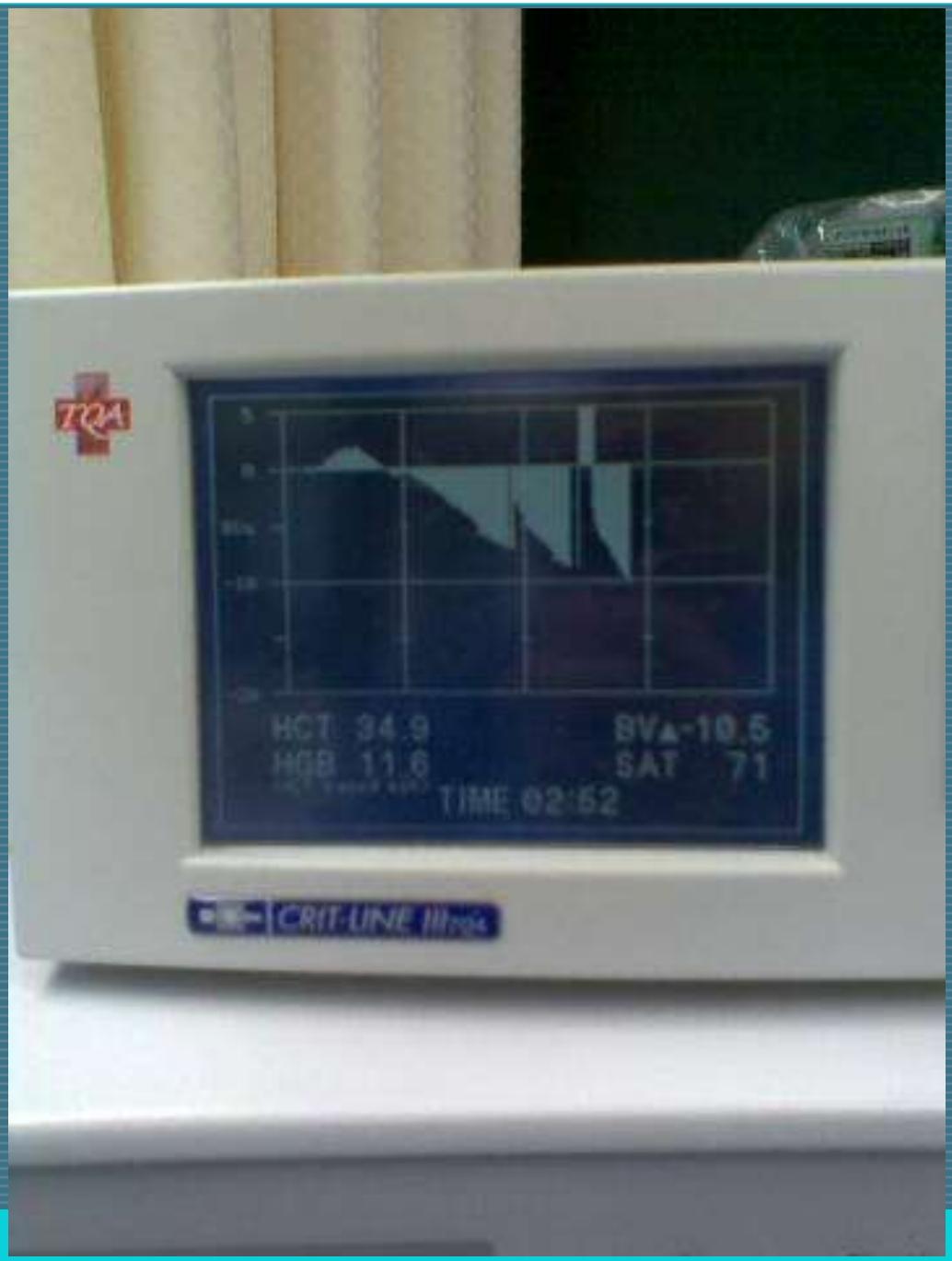
Continuous hematocrit monitoring

- Rationale:
  - Ultrafiltration reduces intravascular fluid volume
  - Intravascular Hct rises as fluid is removed

- Basis of observation: intravascular refill

  - When ultrafiltration is suddenly stopped the instravasc. fluid refill continues and the Hct drops – while fluid overloaded
  - When ultrafiltration is suddenly stopped instravasc. fluid refill stops and the Hct does not drops – while no longer fluid-overloaded

Continuous Hematocrit Monitoring


HCT 34.9
HGB 11.6
BV▲-10.5
SAT 71
TIME 02:52
CRIT-LINE III


TQA
HCT 27.7
BV▲27.8
SAT 91
TIME 03:19
CRITICLINE III
3500
600

Continuous hematocrit monitoring: clinical practice

- Rapid refill occurs when the ECF is expanded as a result of volume overload
  - Steuer RR et al *Artif Organs* 22:627–632, 1998
- Intradialytic hypotensive symptoms can be avoided with Hct monitoring
  - Steuer RR et al *Am J Kidney Dis* 27:525–532, 1996
- Drawback:
  - Expense
  - Need for frequent intervention
  - <u>Outcome</u> studies did not show benefit…

Adjusted risk ratio for hospitalization in IBVM vs conventional-care group

Hospitalization type	Estimate	p
Access-related	1.52	0.04
Nonaccess-related	1.61	0.01
Cardiovascular	1.85	0.006
Other	1.53	0.02

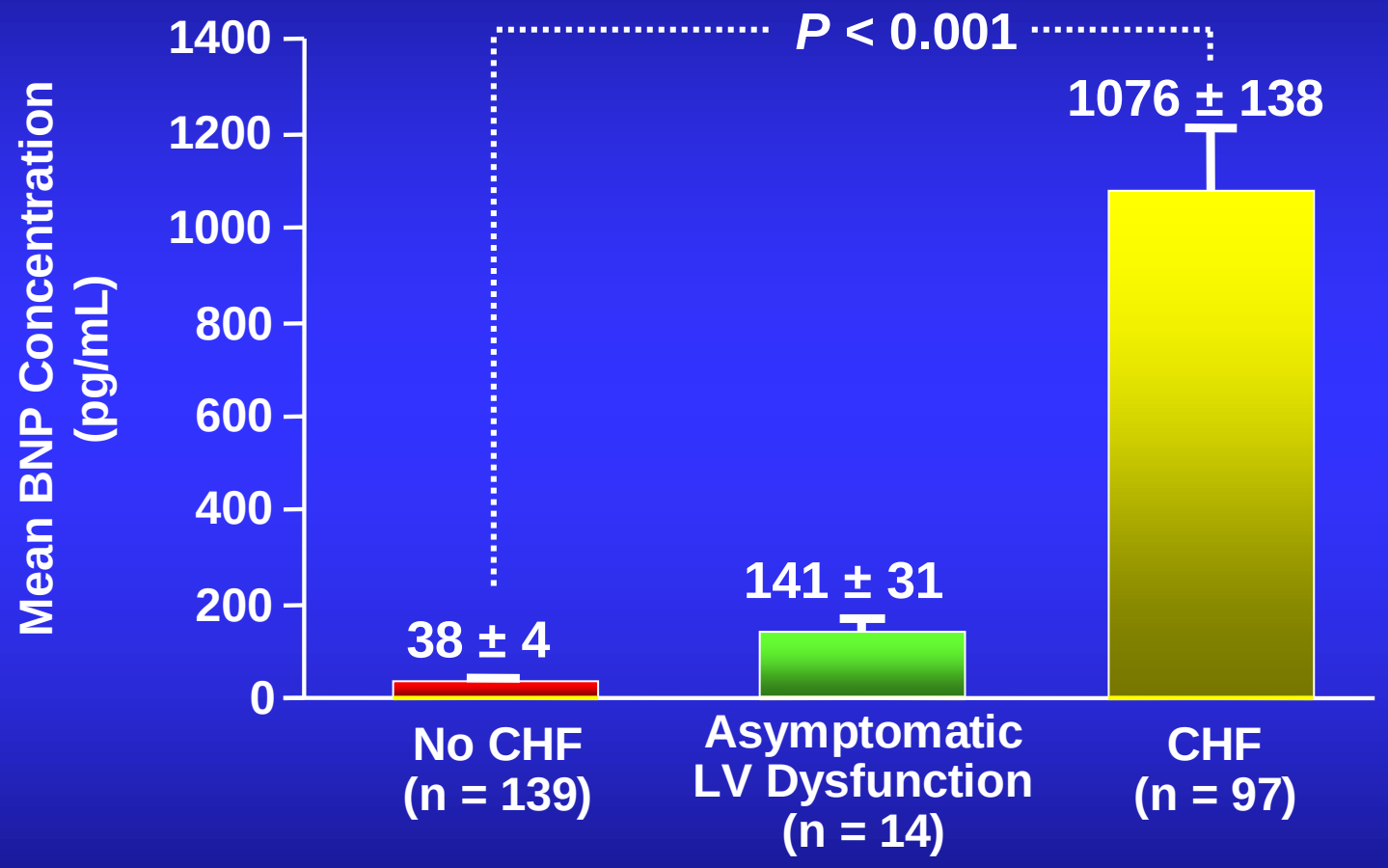
Reddan DN et al. *J Am Soc Nephrol*; available at http://www.jasn.org.

Intravascular volume by BNP in ESRD

- [1, 2]BNP and pro-BNP correlated:
  - With **IVC diameter index**
  - **Blood Volume**
    - Measured with bioimpedence
    - Correlated with interdialytic hypotension
    - **Measured** by pulse dye-densitometry (PDD)
      - a newly developed technique for monitoring the arterial concentration of indocyanine green

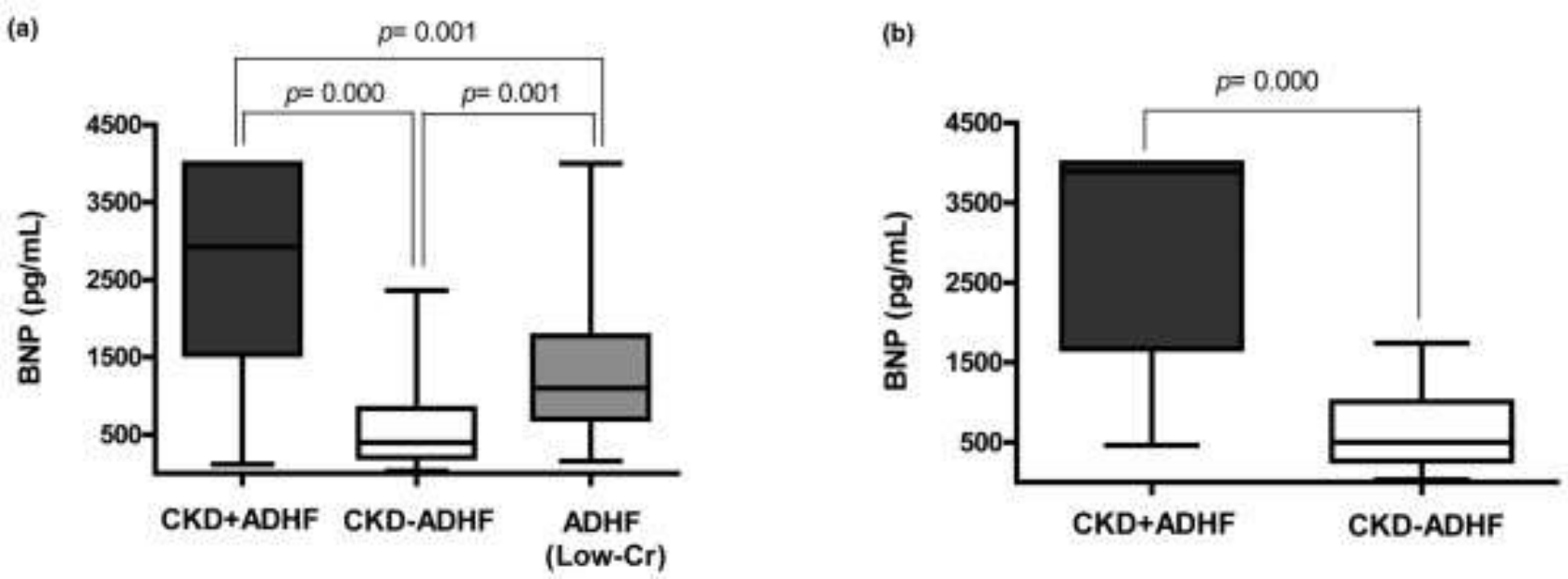
1 van de Pol AC, Frenken LA et al. *Hemodial Int*. 2007 Jan;11(1):51-61
2 Morishita Y, Ando Y et al *Clin Exp Nephrol* 2005 Sep;9(3):233-7

BNP Levels of Patients Without CHF, With Baseline LV Dysfunction, and With CHF



Dao Q et al. *J Am Coll Cardiol.* 2001;37:379–385.

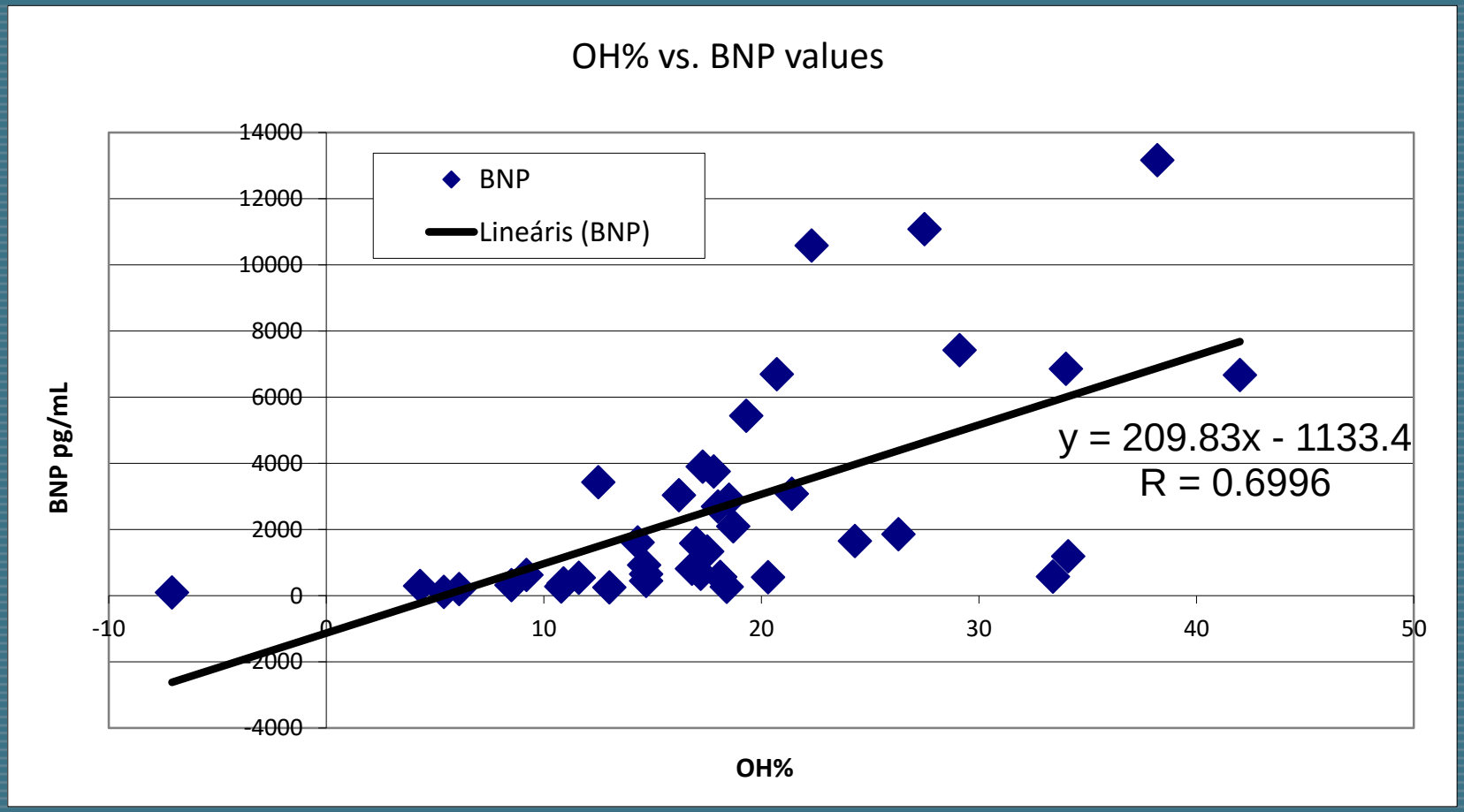
BNP in Acute Decompensated Heart Failure and CKD



Comparison of BNP levels at admission. (a) Brain natriuretic peptide (BNP) levels at admission among three groups: chronic kidney disease (CKD) + acute decompensated heart failure (ADHF) (mean ± standard deviation, 2708.6 ± 1246.9 pg/ml), CKD - ADHF (567.9 ± 491.7 pg/ml) and low-creatinine (Cr; <1.2 mg/dl)/ADHF (1418.9 ± 1126.5 pg/ml). BNP levels at admission were different among the three groups (P = 0.000, analysis of variance) and between each pair of groups (P = 0.001, P = 0.000 and P = 0.001, respectively, Tukey's *post hoc* test) with the highest mean value in the CKD + ADHF group. (b) BNP levels at admission of 58 dialysis-dependent patients with and without ADHF (3047.2 ± 1229.3 pg/ml vs. 632.3 ± 492.2 pg/ml, respectively, P = 0.000).

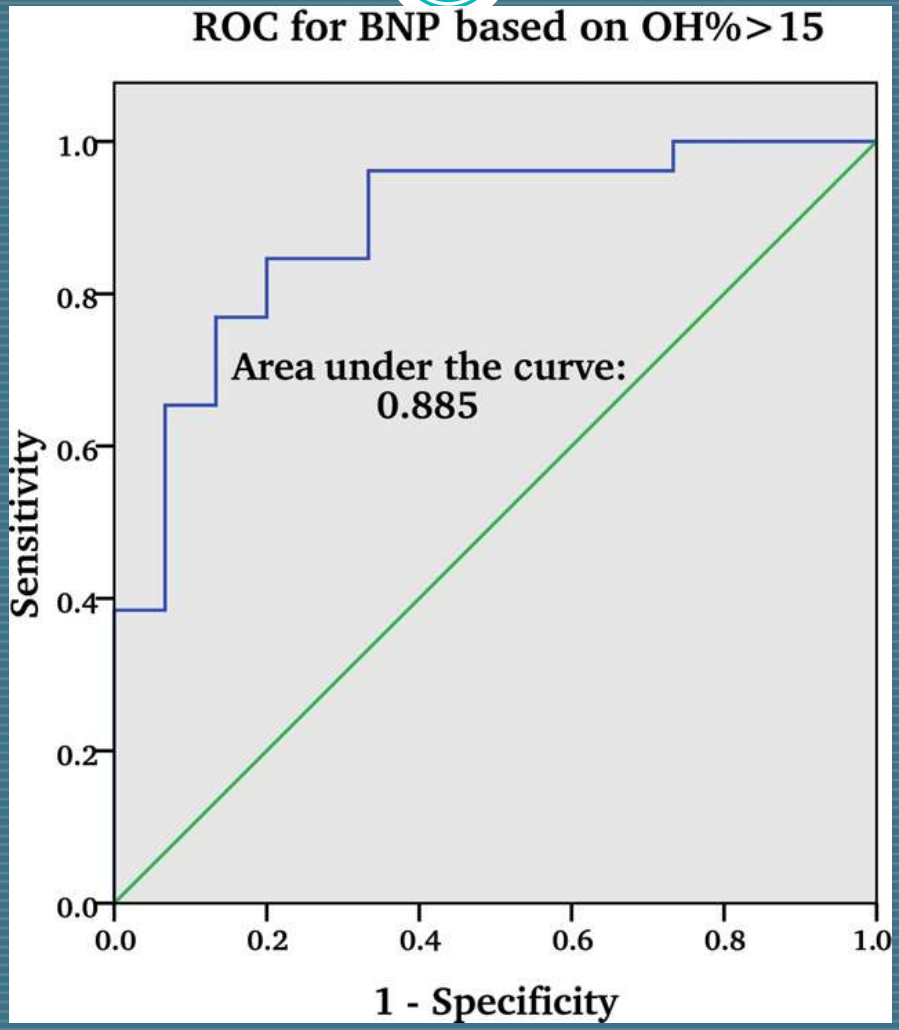
S Park: Crit Care 2009; 13(3): R70.

BNP-predicted overload correspond with bioimpedence predicted OH%



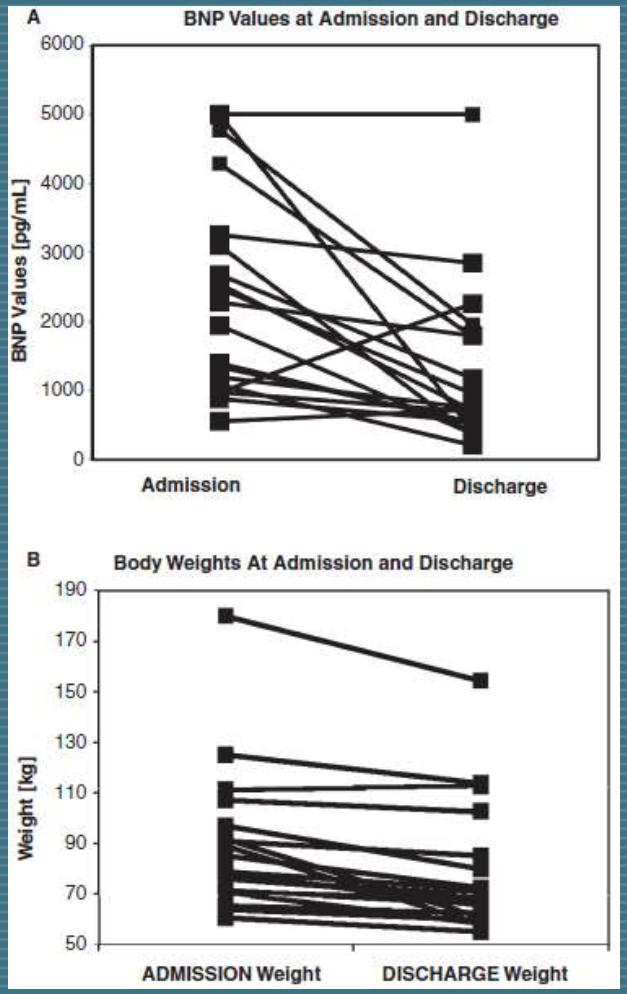
Tapolyai, Faludi, Réti et al. ***Hemodial International 2013 Jan 30 doi: 10.1111/hdi.12023.***

High degree of correspondence between volume assessment methods



Tapolyai, Faludi, Réti et al. ***Hemodial International 2013 Jan 30 doi: 10.1111/hdi.12023.***

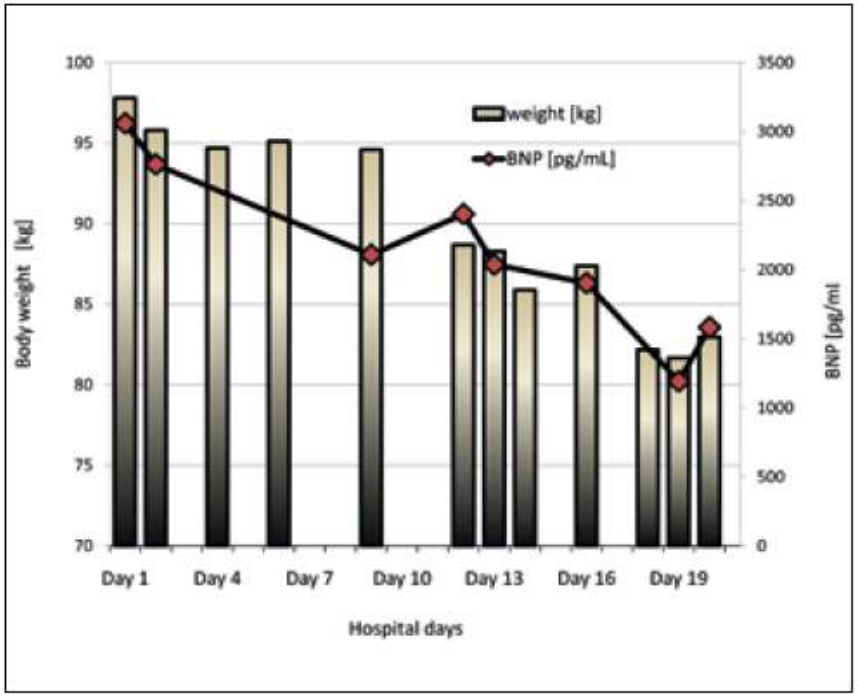
BNP directed UF in Acutely Hospitalized ESRD Patients

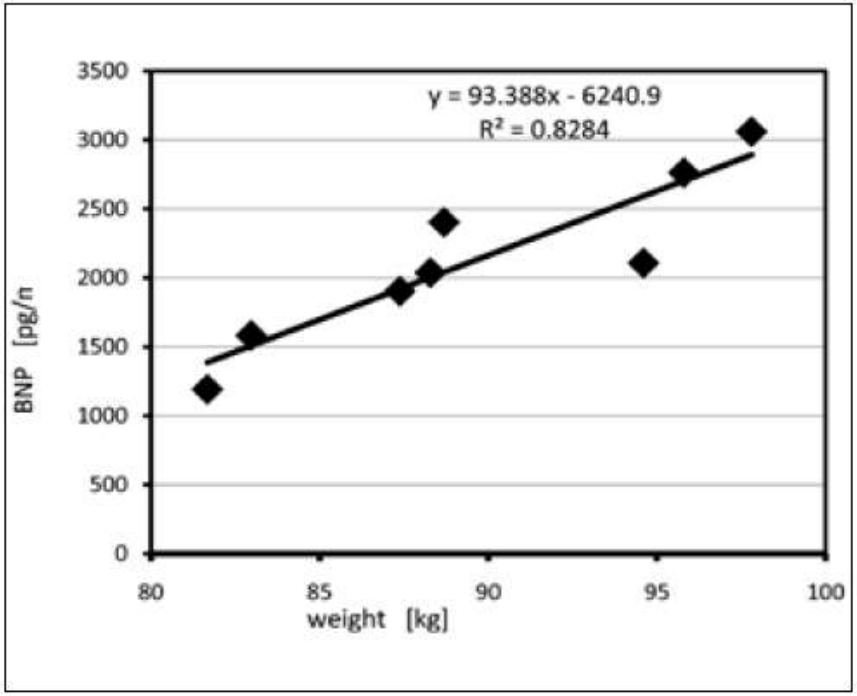


- BNP-directed UF helps to identify patients with occult fluid overload
- BNP-directed UF helps their care:
  - Continued UF below the wrongly estimated Dry Weight
  - Reduce the # of antihypertensive meds
  - Reduce BP
  - Reduce weight

Tapolyai, Uysal, Maeweathers, et al. May/June 2009: 131-135 Congestive Heart Failure

BNP-directed UF

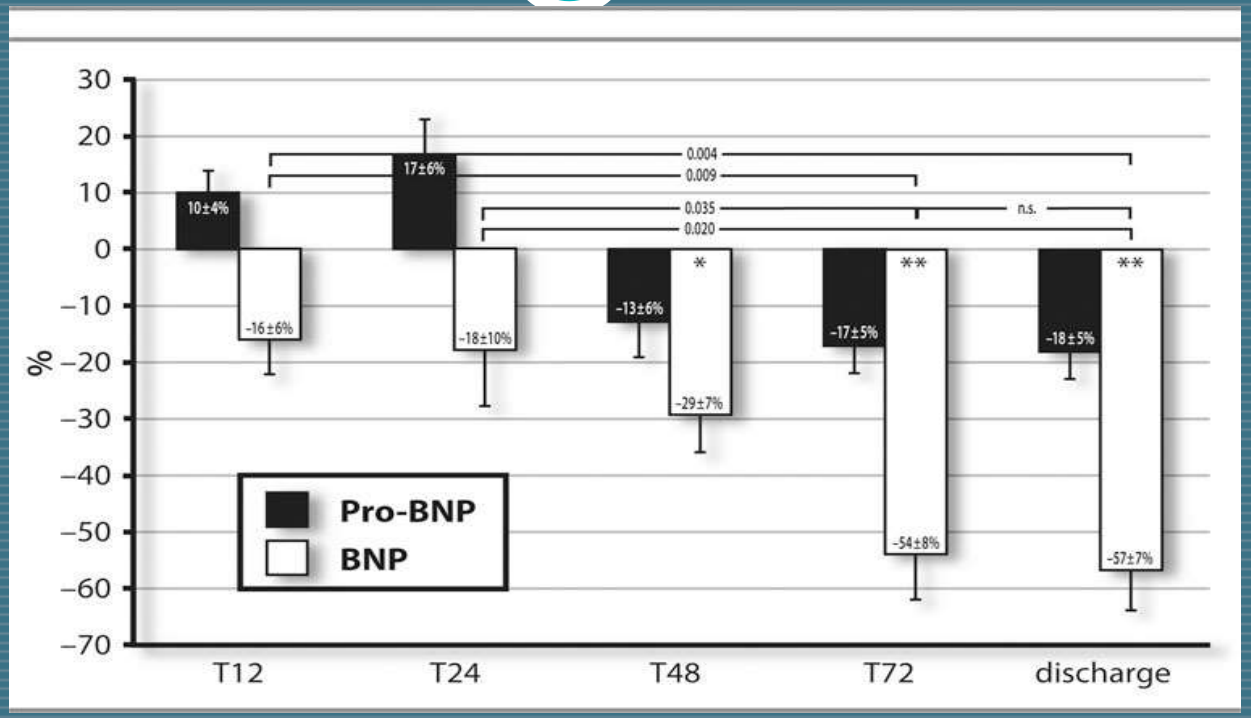




- BNP directed UF in a case report, shown to improve UF (15.5 L in 21 hospital days), blood pressure and polypharmacy

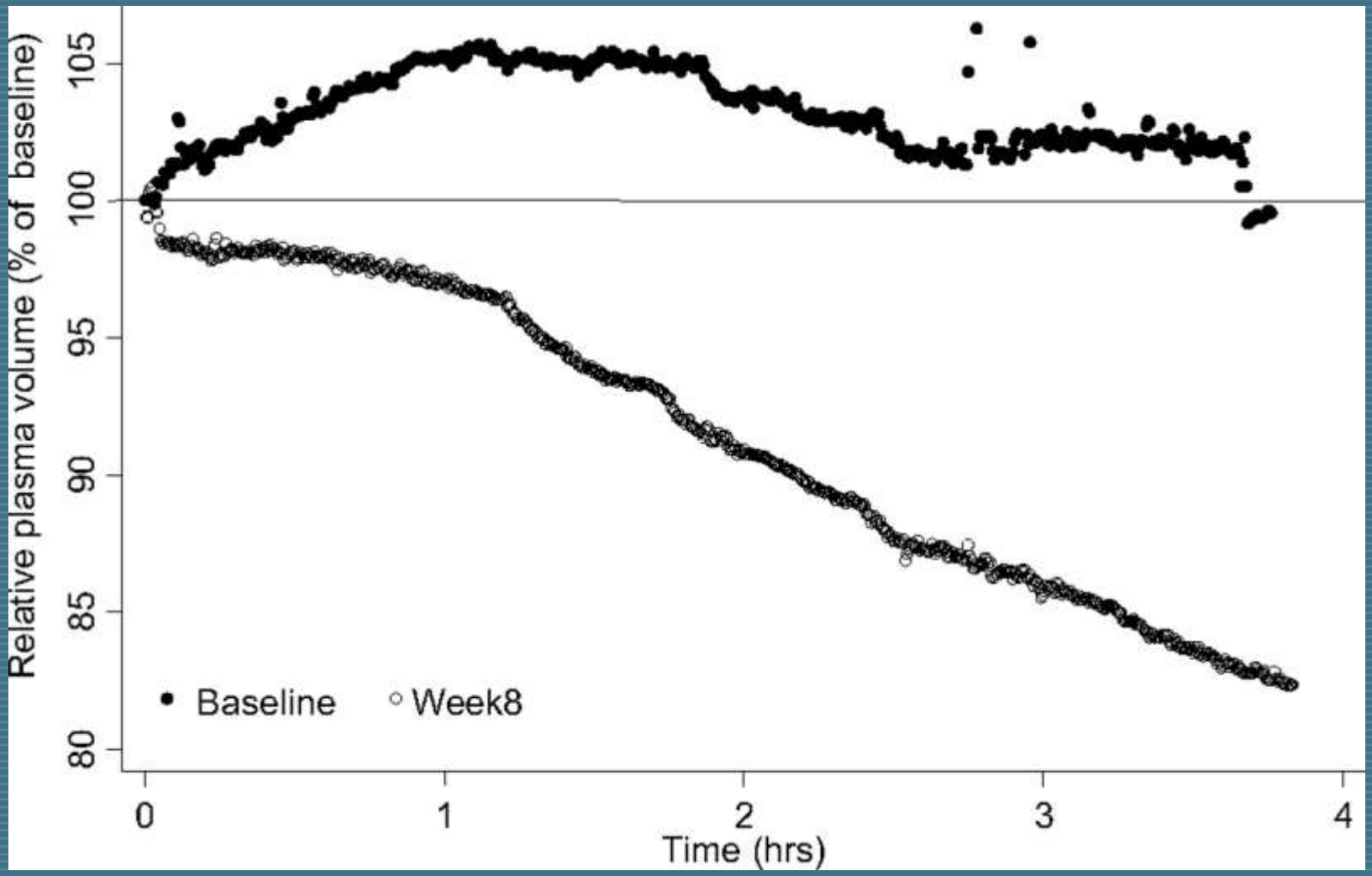
Tapolyai, .Fülöp: April-June; 2010; 11: 00-00 JOURNAL OF VASCULAR ACCESS [ePub: 16/02/2010]

BNP vs. NTpro-BNP



- Percentage variation of B-type natriuretic peptide (BNP) and N-terminal prohormone brain natriuretic peptide and (NTproBNP) after treatment in patients with acute decompensated heart failure from admission to discharge.
- Ntpro=-BNP is not suitible to monitor volume in ESR
- Salvatore DiSomma et al. Congest HeartFail 2008 Jul-Aug;14(4 Suppl 1):21-4.

Example of RPV monitoring as an indicator of dry-weight.



Rajiv Agarwal, and Matthew R. Weir CJASN 2010;5:1255-1260

CJASN

Multifrequency Bioimpedance

- High frequency (high energy) electricity travels through all the tissues → it can measure Total Body Water (TBW)
- Low frequency electricity travels through the extracellular space only → it can measure Extracellular Water (only)
- All other indices are calculated
- Validation was through isotopes: D2O (heavy water), Bromide isotopes, K isotopes etc.
- Clinically utilizable instrument: Body Composition Measure (BCM)

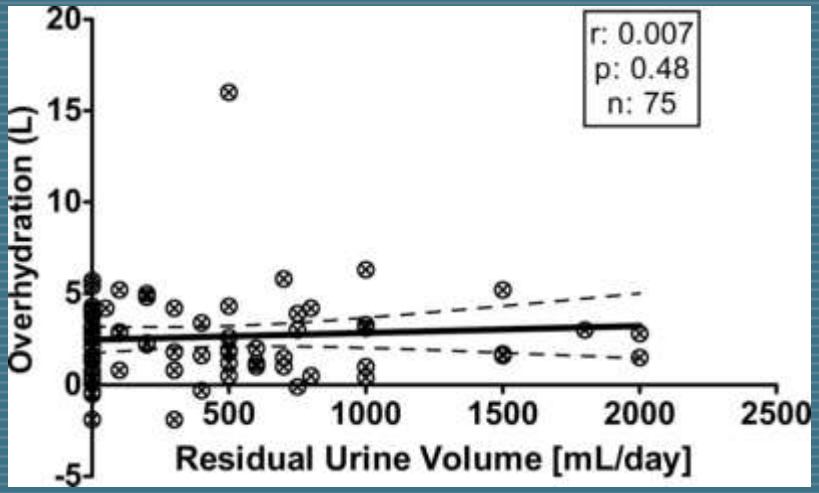
Clinical Use of Multifrequency Bioimpedance

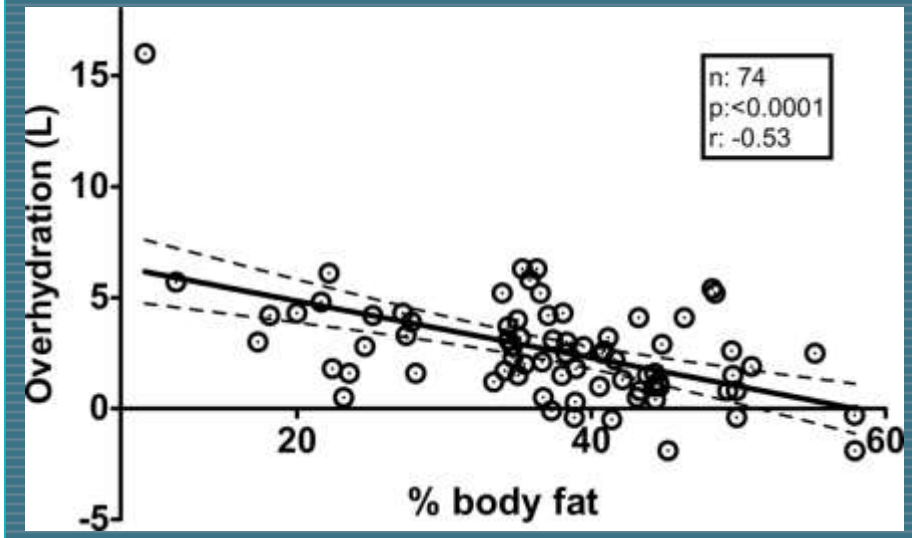
- It can measure both overhydration and fluid deficit:
  - Calculated from E/I ratio
- It can quantitate (how many liters) fluid deficit or excess

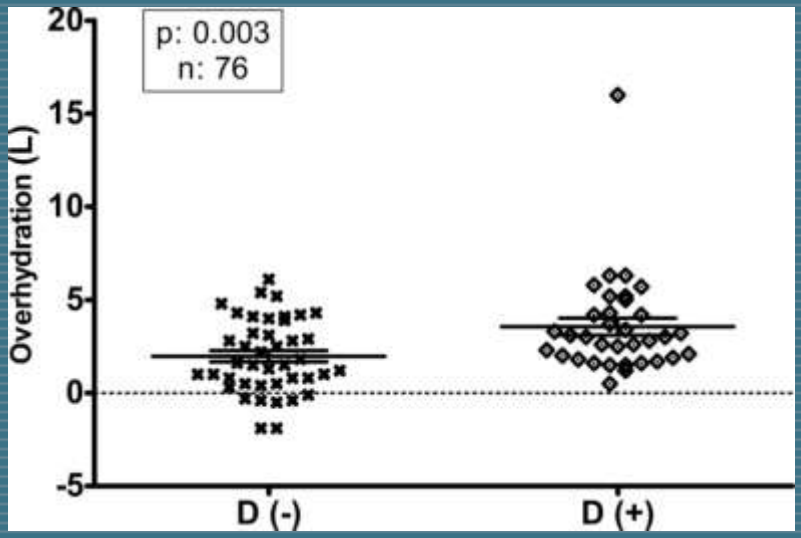
Clinical use of BCM

Achieving BCM-measured Dry Weight (absence of overhydration)

- ...little to do with residual renal function or diuretics use
- There is an inverse relationship with obesity and OH
- Conventional clinical wisdom may not always hold when fluid spaces are measured







Tapolyai M. et al. ASAIO J, Nov/Dec 2011 - Vol57;6

Summary

- Dry Weight is an essential part of dialysis adequacy
- Measuring fluid volumes and guiding dry weight targets is essential to avoid both fluid depletion and fluid overload
- Fluid volume measurements is evidence based medicine
- Emerging technologies will enable us to better estimate dry weight…
  - …but will that improve outcome?