Intensive Care Nephrology

Fluid Management In Critically Ill Patients

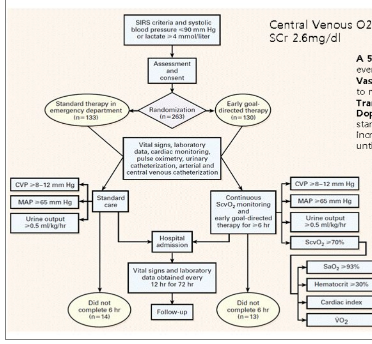
Jongwon Park, M.D., Ph.D.

Yeungnam University Medical Center

CONTENTS

1. Early Goal-Directed Therapy
2. Choice of Resuscitation Fluid
3. Risk of Fluid Overload
4. Diuretics Use
5. Monitoring of Volume Status and Responsiveness
6. Summary

1. EARLY GOAL-DIRECTED THERAPY in the Treatment Of **Septic Shock with AKI**



Central Venous O2 saturation<50%
SCr 2.6mg/dl

A 500-ml bolus of crystalloid,
every 30 minutes to achieve **a CVP of 8 to 12 mmHg**
Vasopressors or vasodilators,
to maintain **a MAP of at least 65 mm Hg**
Transfusion, upto Hct>30%
Dopatamine,
started at a dose of 2.5 μg/kg/min,
increased by 2.5 μg/kg/min every 30 minutes
until the **CV SaO2 upto 70 % or higher**

Although **more fluid** was administ- ered from 0 to 6 hours in the ED, the EGDT group received **less fluid** during hours 7 to 72 and fewer of these patients were on mechanical ventilation (2.6% versus 16.8%, P<0.001)

N Engl J Med 2001

Beneficial effects of EGDT

Table 1. Sepsis and septic shock (0 to 6 hours)[a]

	Standard	Early Goal	*P* Value
MAP (mmHg)	81 ± 16	88 ± 16	<0.001
$SCVO_2 \geq 70\%$	60.2%	94.9%	<0.001
CVP, MAP, and UO Goals	86.1%	99.2%	<0.001

Table 2. Beneficial effects of EGDT of severe sepsis and septic shock (7 to 72 hours)[a]

	Standard	Early Goal	*P* Value
In-hospital mortality (%)	46.5	30.5	<0.009
$SCVO_2$ (%)	65.3	70.4	<0.02
Lactate (mmol/L)	3.9	3.0	<0.02
PH	7.36	7.4	<0.02
Mechanical ventilation (%)	16.8	2.6	<0.001
Fibrin split product (μg/dl)	62	39	<0.001

Clin J Am Soc Nephrol, 2010

Harmonizing international trials of **early goal-directed** resuscitation for severe sepsis and septic shock

- Three current trials

① ProCESS: **Pro**tocolized **C**are for **E**arly **S**eptic **S**hock in USA

② ARISE: **A**ustralasian **R**esuscitation **I**n **S**epsis **E**valuation

③ ProMISe: **Pro**tocolised **M**anagement **I**n **Se**psis in UK

- Each trial is a patient-level, equal-randomized, parallel-group superiority trial that seeks to enroll emergency department patients with inclusion criteria that are consistent with the original EGDT trial, is powered to detect a **6–8% absolute mortality reduction (hospital or 90-day).**

Intensive Care Med. 2013

2. Choice of Resuscitation Fluid

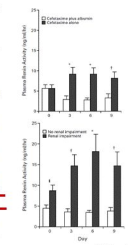
- Remains controversial.
- Globally, **0.9% sodium chloride (saline)** is the most commonly used fluid, although colloids are administered as often as crystalloids, and hydroxyethyl starch (HES) is the most frequently used colloid.

EFFECT OF INTRAVENOUS ALBUMIN ON RENAL IMPAIRMENT AND MORTALITY IN PATIENTS WITH CIRRHOSIS AND SPONTANEOUS BACTERIAL PERITONITIS

126 patients with cirrhosis and SBP to treatment with i.v. cefotaxime (63 patients) or cefotaxime and i.v. albumin (1.5g/kg) (63 patients) in Spain

TABLE 2. CLINICAL OUTCOME ACCORDING TO THE ASSIGNED TREATMENT.*

OUTCOME VARIABLE	CEFOTAXIME (N=63)	CEFOTAXIME PLUS ALBUMIN (N=63)	P VALUE
Resolution of infection — no. (%)†	59 (94)	62 (98)	0.36
Duration of antibiotic therapy — days	6±1	5±1	0.48
Paracentesis for ascites after resolution of infection — no. (%)‡	16 (25)	14 (22)	0.83
Hospital stay — days	13±1	14±1	0.48
Renal impairment — no. (%)	21 (33)	6 (10)	0.002
Death — no. (%)			
In hospital§	18 (29)	6 (10)	0.01
At three months¶	26 (41)	14 (22)	0.03

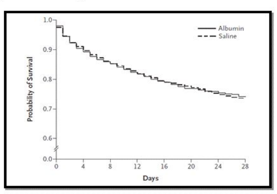


N Engl J Med 1999

The Saline *versus* Albumin Fluid Evaluation (SAFE)

A Comparison of Albumin and Saline for Fluid Resuscitation in the Intensive Care Unit
The SAFE Study Investigators*

N=3497 in 4% albumin (28.7→29 g/L)
N=3500 in saline (24.7→23.1 g/L)
Days spent in the ICU
Days of mechanical ventilation
Days of RRT
Mortality



Isotonic crystalloid solutions should be the preferred resuscitation fluid in critically ill patients.

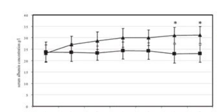
N Engl J Med 2004

Albumin administration improves organ function in critically ill hypoalbuminemic patients: A prospective, randomized, controlled, pilot study

The 100 patients were randomized to receive 300 mL of 20% albumin solution on the first day, then 200 mL/day provided their serum albumin concentration was <31 g/dL (albumin group), or to receive no albumin (control group).

A delta Sequential Organ Failure Assessment score from day 1 to day 7

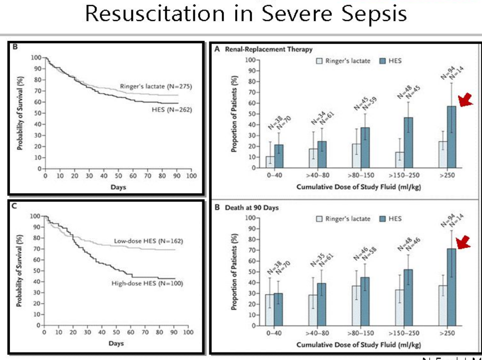
SOFA Score
Respiration, Pao_2/FIo_2, mm Hg
Coagulation, platelets × $10^3/mm^3$
Liver, bilirubin, mg/dL (μmol/L)
Cardiovascular, hypotension
Central nervous system, Glasgow Coma Scale score
Renal, creatinine, mg/dL, (μmol/L)
Or urine output



	Control Group (n = 50)	Albumin Group (n = 50)	*p* Value
Baseline SOFA	5.7 ± 0.8	6.3 ± 0.8	.31
Last SOFA	4.6 ± 1.2	4.1 ± 1.1	.65
Delta SOFA	1.4 ± 1.1	3.1 ± 1.0	.03

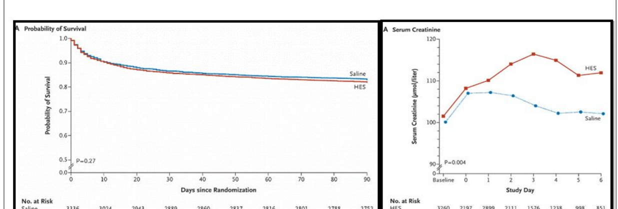
Crit Care Med 2006

Intensive Insulin Therapy and Pentastarch Resuscitation in Severe Sepsis



N Engl J Med, 2006

Hydroxyethyl Starch or Saline for Fluid Resuscitation in Intensive Care



In patients in the ICU, there was **no significant difference in 90-day mortality** between patients resuscitated with 6% HES (130/0.4) or saline. However, **more** patients who received resuscitation with HES were treated with **renal-replacement therapy**.

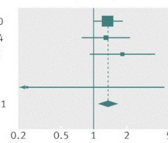
N Engl J Med, 2013

Hydroxyethyl starch 130/0.38-0.45 versus crystalloid or albumin in patients with sepsis: systematic review with meta-analysis and trial sequential analysis.

Study	Events/total: Hydroxyethyl starch	Events/total: Crystalloid or albumin	Weight (%)	Risk ratio (95% CI)
Low risk of bias				
6S[9]	87/398	65/400	64.4	1.35 (1.01 to 1.80)
BaSES[51]	28/117	23/124	22.2	1.29 (0.79 to 2.11)
CRYSTMAS[11]	21/100	11/96	11.2	1.83 (0.93 to 3.59)
Dolecek 2009[53]	0/26	0/30		Not estimable
Dubin 2010[54]	0/9	2/11	2.3	0.24 (0.01 to 4.44)
Total (95% CI)	136/650	101/661	100.0	1.36 (1.08 to 1.72)

Test for heterogeneity: χ^2=2.16, df=3, P=0.54, I^2=0%

Test for overall effect: z=2.61, P=0.009



In conventional meta-analyses including recent trial data, hydroxyethyl **starch** 130/0.38-0.45 versus crystalloid or albumin **increased the use of RRT** and transfusion with red blood cells, and resulted in **more serious adverse events** in patients with sepsis.

BMJ. 2013

Colloids versus crystalloids for fluid resuscitation in critically ill patients.

- 78 eligible trials
- **CONCLUSIONS:**

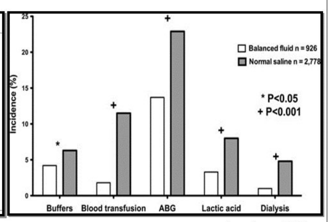
There is **NO** evidence from RCTs that resuscitation with **colloids reduces the risk of death**, compared to resuscitation with crystalloids, in patients with trauma, burns or following surgery. Furthermore, the use of hydroxyethyl starch might **increase mortality**. As colloids are not associated with an improvement in survival and are **considerably more expensive** than crystalloids, it is hard to see how their continued use in clinical practice can be justified.

Cochrane Database Syst Rev. 2013

Major complications, mortality, and resource utilization after open abdominal surgery: 0.9% saline compared to Plasma-Lyte.

- 0.9% saline may cause hyperchloremic metabolic acidosis, and may give rise to adverse effects including immune dysfunction, G-I dysfunction, and decreased renal blood flow.

Electrolyte	Plasma	0.9% NaCl	Ringer's lactate, Hartmann's	Plasma-Lyte®
Sodium	140	154	131	140
Potassium	5	0	5	5
Chloride	100	154	111	98
Calcium	2.2	0	2	0
Magnesium	1	0	1	1.5
Bicarbonate	24	0	0	0
Lactate	1	0	29	0
Acetate	0	0	0	27
Gluconate	0	0	0	23
Maleate	0	0	0	0



Ann Surg. 2012

KDIGO Clinical Practice Guideline for Acute Kidney Injury, 2012

FLUIDS

3.1.1: In the absence of hemorrhagic shock, we suggest using **isotonic crystalloids** rather than **colloids(albumin or starches)** as initial management for expansion of intra-vascular volume in patients at risk for AKI or with AKI. (2B)

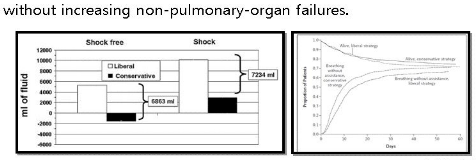
3. Risk of Fluid overload Administration in Critically Ill Patients with AKI

- Patients in the EGDT group had a significantly higher volume of fluid administered during the first 6 hours (4981 mL vs 3499 mL), and both groups received more than 13 L over 72 hours.
- In critically ill patients with AKI, **mortality** rates range from 50 to 70% and have usually been attributed to multiple complications related to AKI, such as **infections, bleeding**, and **fluid overload.**

Clin J Am Soc Nephrol, 2010
J Am Soc Nephrol 2006; 17: 1143–1150
Clin Nephrol 1994; 41: 342–349
Intensive Care Med 2004; 30: 1886–1890

Comparison of two fluid-management strategies in acute lung injury

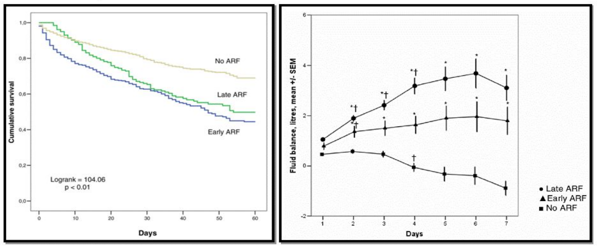
- 1,000 pts with acute lung injury, CVP or PAOP, MAP, Oliguria, C.I.
- Liberal-strategy group: CVP of 10-14mmHg and PAOP of 14-18 mmHg
- Conservative-strategy group: CVP of < 4mmHg and PAOP<8mmHg
- The conservative strategy of fluid management improved lung function and shortened the duration of mechanical ventilation and intensive care without increasing non-pulmonary-organ failures.



N Engl J Med, 2006

A positive fluid balance is associated with a worse outcome in patients with acute renal failure.

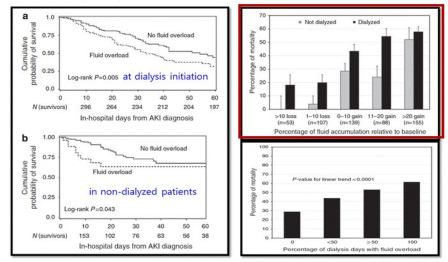
- Sepsis Occurrence in Acutely Ill Patients (**SOAP**) Investigators
- 3,147 pts



Critical Care 2008

Fluid accumulation, survival and recovery of kidney function in critically ill patients with acute kidney injury

- **P**rogram to **I**mprove **C**are in **A**cute **R**enal **D**isease (**PICARD**) Study
- 618 pts in a prospective multicenter observational study.



Kidney International (2009)

Initial Fluid Resuscitation(**IFR**) FROM 6 HRS & Late Fluid Management (**LFM**) TO 7 DAYS

Measured intravascular pressure (mm Hg)				MAP <60 mm Hg or a need for any vasopressor (except dopamine ≤5 μg/kg/min); consider correctable causes of shock first	MAP ≥60 mm Hg without vasopressors (except dopamine ≤5 μg/kg/min)			
CVP		PAOP[G]			Average urinary output <0.5 ml/kg/hr		Average urinary output ≥0.5 ml/kg/hr	
Conservative strategy	Liberal strategy	Conservative strategy	Liberal strategy		**Ineffective Circulation** Cardiac index <2.5 liters/min/m² or cold, mottled skin with capillary-refilling time >2 sec	**Effective Circulation** Cardiac index ≥2.5 liters/min/m² or absence of criteria for ineffective circulation	**Ineffective Circulation** Cardiac index <2.5 liters/min/m² or cold, mottled skin with capillary-refilling time >2 sec	**Effective Circulation** Cardiac index ≥2.5 liters/min/m² or absence of criteria for ineffective circulation
Range 1				1 Vasopressor[F] Fluid bolus[F]	3 KVO IV Dobutamine[A] Furosemide[B,1,2,4]	7 KVO IV Furosemide[B,1,2,4]	11 KVO IV Dobutamine[A] Furosemide[B,1,3,4]	15 KVO IV Furosemide[B,1,3,4]
>13	>18	>18	>24					
Range 2					4 KVO IV Dobutamine[A]	8 KVO IV Furosemide[B,1,2,4]	12 KVO IV Dobutamine[A]	16 KVO IV Furosemide[B,1,3,4]
9–13	15–18	13–18	19–24					
Range 3				2 Fluid bolus[F] Vasopressor[F]	5 Fluid bolus[C]	9 Fluid bolus[C]	13 Fluid bolus[C]	17 Liberal KVO IV; 18 Conservative Furosemide[B,1,3,4]
4–8	10–14	8–12	14–18					
Range 4					6 Fluid bolus[C]	10 Fluid bolus[C]	14 Fluid bolus[C]	19 Liberal fluid bolus; 20 Conservative KVO IV
<4	<10	<8	<14					

N Engl J Med, 2006

Late Fluid Management (LFM)

- The largest RCT performed on LFM, the Fluids and Catheters Treatment Trial (**FACTT**), showed a negative effect of fluid accumulation on pulmonary function but failed to show an improved survival with a conservative fluid strategy.

Table 3. Main Outcome Variables.*

Outcome	Conservative Strategy	Liberal Strategy	P Value
Death at 60 days (%)	25.5	28.4	0.30
Ventilator-free days from day 1 to day 28†	14.6±0.5	12.1±0.5	<0.001
ICU-free days†			
Days 1 to 7	0.9±0.1	0.6±0.1	<0.001
Days 1 to 28	13.4±0.4	11.2±0.4	<0.001
Dialysis to day 60			
Patients (%)	10	14	0.06
Days	11.0±1.7	10.9±1.4	0.96

Table 3. Main Outcome Variables.*

Outcome	Conservative Strategy	Liberal Strategy	P Value
Organ-failure–free days†‡			
Days 1 to 7			
Cardiovascular failure	3.9±0.1	4.2±0.1	0.04
CNS failure	3.4±0.2	2.9±0.2	0.02
Renal failure	5.5±0.1	5.6±0.1	0.45
Hepatic failure	5.7±0.1	5.5±0.1	0.12
Coagulation abnormalities	5.6±0.1	5.4±0.1	0.23
Days 1 to 28			
Cardiovascular failure	19.0±0.5	19.1±0.4	0.85
CNS failure	18.8±0.5	17.2±0.5	0.03
Renal failure	21.5±0.5	21.2±0.5	0.59
Hepatic failure	22.0±0.4	21.2±0.5	0.18
Coagulation abnormalities	22.0±0.4	21.5±0.4	0.37

N Engl J Med, 2006

Late Fluid Management (LFM)

- The mean cumulative fluid balance during the first seven days was - 136±491 ml in the conservative-strategy group and 6992 ±502 ml in the liberal-strategy group (P<0.001).
- As compared with the liberal strategy, the **conservative strategy** did not increase the incidence or prevalence of shock during the study or the use of dialysis during the first 60 days (P = 0.06).

Table 2. Furosemide Dose, Fluid Intake, Fluid Output, and Fluid Balance on Each Day during the Study.*

Day	Furosemide		Fluid Intake		Fluid Output		Fluid Balance	
	Liberal	Conservative	Liberal	Conservative	Liberal	Conservative	Liberal	Conservative
	mg/24 hr (no. of patients)		*ml/24 hr (no. of patients)*		*ml/24 hr (no. of patients)*		*ml/24 hr (no. of patients)*	
1	74.27±7.48 (133)	148.94±8.52 (312)	5029.8±132.98 (485)	4230.5±120.03 (491)	2501.9±73.23 (485)	3043.8±93.90 (491)	2529.5±148.99 (484)	1186.7±151.01 (491)
2	72.46±6.65 (146)	157.35±8.91 (304)	4467.4±136.11 (479)	3590.6±98.45 (480)	2824.5±101.44 (479)	3966.7±115.57 (480)	1642.9±151.71 (479)	−376.1±161.08 (480)
3	65.28±6.49 (140)	166.90±10.01 (269)	3997.1±103.40 (465)	3390.4±85.30 (464)	3060.9±103.23 (465)	3797.3±110.48 (465)	936.12±115.32 (465)	−408.5±135.90 (464)
4	80.74±10.23 (129)	154.25±10.61 (228)	3752.0±102.07 (444)	3430.8±96.49 (437)	3188.1±109.19 (444)	3606.1±113.38 (434)	563.88±100.98 (444)	−165.5±119.92 (434)
5	73.06±8.41 (119)	164.71±12.06 (197)	3825.3±110.62 (424)	3201.1±87.23 (411)	3358.7±115.49 (421)	3444.8±108.98 (408)	483.03±109.98 (421)	−226.3±115.22 (408)
6	58.20±6.68 (106)	158.87±13.45 (165)	3782.8±104.28 (411)	3159.4±88.12 (382)	3334.4±123.99 (411)	3316.9±103.81 (379)	508.04±111.75 (410)	−144.9±110.25 (378)
7	51.03±4.31 (87)	127.86±11.61 (137)	3639.7±93.96 (390)	3226.9±108.18 (355)	3216.8±98.36 (385)	3143.9±100.16 (346)	458.95±106.85 (385)	130.08±118.47 (346)

The Importance of Fluid Management in ALI Secondary to Septic Shock

- **IFR** was "adequate" if a fluid bolus greater than 20 mL/kg was administered before vasopressor treatment initiation and if patients had a CVP > 8 mmHg during the 6 first hours.
- For **LFM**, "conservative" strategy was defined as even-to negative fluid balance for 2 or more consecutive days during the first week.
- **Hospital mortality was lowest** for those achieving an adequate IFR and a conservative LFM (18%).

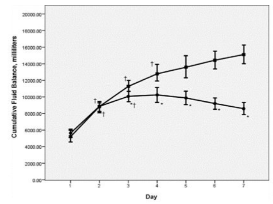
Chest. 2009;136:102-109

CHEST

Date of download: 4/9/2013

From: The Importance of Fluid Management in Acute Lung Injury Secondary to Septic Shock

Chest. 2009;136(1):102-109. doi:10.1378/chest.08-2706



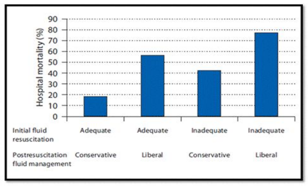


Figure Legend:

Mean (± SE) cumulative daily fluid balance (in milliliters) for days 1 through 7 following the onset of septic shock. Nonsurvivors are depicted by squares, and survivors by circles. * = $p < 0.05$ pairwise compared between survivors and nonsurvivors (ANOVA for repeated measures); † = $p < 0.05$ compared with the previous time point (ANOVA for repeated measures).

Fluid Management and Use of Diuretics in Acute Kidney Injury

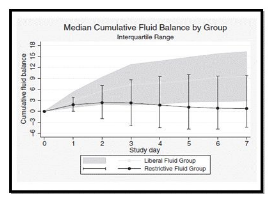
- The timing and amount of volume to be administered to prevent AKI and other organ damage is still debated, but an aggressive **fluid repletion in the early setting** is probably beneficial.
- However, **fluid overload** has also been associated with increased mortality and reduced rate of kidney recovery in observational studies in critically ill patients with AKI.
- **Diuretics** may prevent or treat fluid overload and may also affect kidney function?

Advances in Chronic Kidney Disease, 2013

Fluid Balance, Diuretic Use, and Mortality in Acute Kidney Injury

- Using data from the Fluid and Catheter Treatment Trial (**FACTT**), a multicenter, RCT evaluating a conservative *versus* liberal fluid-management strategy in 1000 patients with ALI
- A positive fluid balance after AKI was strongly associated with mortality.
- Post-AKI **diuretic therapy** was associated with 60-day patient **survival** in FACTT patients with ALI; this effect may be mediated by fluid balance.

Clin J Am Soc Nephrol, 2011



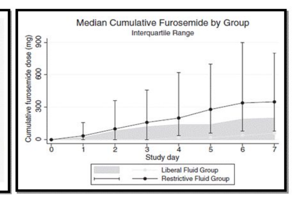


Table 2. Variables associated with 60-day survival among FACTT participants with AKI

FACTT Participants with AKI	Survivors	Nonsurvivors	*P*
AKI stage			
1	65.6	49.2	0.009
2	15.1	17.5	
3	19.4	33.3	
Day of AKI onset (mean)	1.3	1.2	0.497
On-study parameters[b]			
Mean CVP (mmHg)	11.2	13.3	<0.001
Proportion of days in shock (mean)	19.4	52.0	<0.001
Dialysis within the first 7 days (%)	20.4	42.5	<0.001
Early oliguria (%)	28.5	50.8	<0.001
Average daily fluid balance (mean L per day)	0.3	3.3	<0.001
Average daily furosemide dose (mean mg per day)	73.5	25.6	<0.001

Clin J Am Soc Nephrol, 2011

Studies examining the effects of diuretics in AKI.

Reference	Study type	Population	*n*	Effect of diuretics
Mehta et al. (2002) [27]	Retrospective cohort	Patients in 4 teaching hospital ICUs affiliated with the University of California with nephrology consultations, medical and surgical ICU patients	552	Increased risk of death or nonrecovery of renal function (OR 1.77), magnified when patients who died within the first week after consultation were excluded (OR 3.12)
Uchino et al. (2004) [28]	Prospective multicenter, epidemiological study	ICU patients with the following etiologies of AKI: severe sepsis/septic shock (43.8%), major surgery (39.1%), low cardiac output 29.7%), hypovolemia (28.2%)	1734	No statistically significant difference in groups with or without diuretic use
Shiliday et al. (1997) [29]	Prospective, randomized, double-blind placebo-controlled trial	ICU patients at a single center	92	Increase in urine output with diuretics Improvement in mortality for those who became nonoliguric but had lower APACHE II scores at baseline. No difference in mortality between those who became nonoliguric with placebo versus diuretics
Cantarovich et al. (2004) [30]	Prospective, randomized, double-blind, placebo-controlled trial	Multicenter trial, 13 ICUs, 10 nephrology wards	338	Increase in urine output with diuretics No improvement in survival, renal recovery, number of dialysis sessions, or duration of need for dialysis between the two groups
Van der Voort et al. (2009) [31]	Prospective, randomized, double-blind, placebo-controlled trial	ICU patients at a single center treated with CVVH	72	Increase in urine output with diuretics. No improvement in duration of renal failure or rate of renal recovery
Wu et al. (2012) [32]	Prospective, multicenter, observational study	Postsurgical ICU patients receiving hemodialysis	572	Higher doses of diuretics were associated with hypotension and increased mortality

4. Diuretics for management of the volume overload

- While **diuretics did NOT improve clinical outcomes**, they were effective in improving the urine output in those patients who could respond to them.
- Patients with **non-oliguric** AKI either de novo or in response to diuretics may have had **better outcomes** than those with oliguric AKI due to a **lower level of severity of their primary etiology** of AKI compared to the oliguric patients.
- Diuretics should be used in patients with AKI in the ICU for the **management of the volume overload**, **rather than just for converting** patients from oliguric to nonoliguric AKI.

Critical Care Research and Practice, 2013

KDIGO Clinical Practice Guideline for Acute Kidney Injury, 2012

3.4.1: We recommend not using diuretics to prevent AKI. (1B)

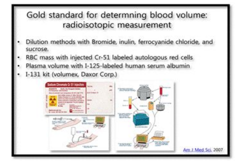
3.4.2: We suggest not using diuretics to treat AKI, except in the management of volume overload. (2C)

Kidney International Supplements, 2012

5. Monitoring of Volume Status

- History & P/E
- Non-invasive: BNP
  - Respiratory variation of IVC diameter
  - BIA
- Invasive: PCWP
  - $ScvO_2$
  - Stroke Volume Variation
  - Pulse Pressure Variation

Rapidity
Accuracy
Invasiveness
Portability
Cost

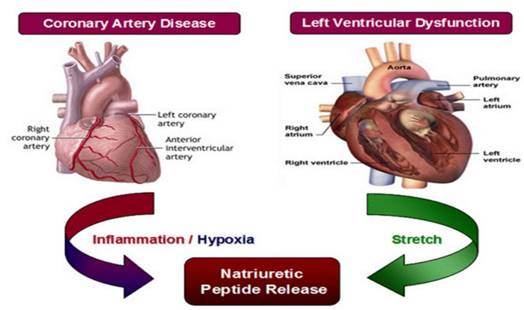


Diagnostic accuracy of Hx. & P/E for the presence of volume overload

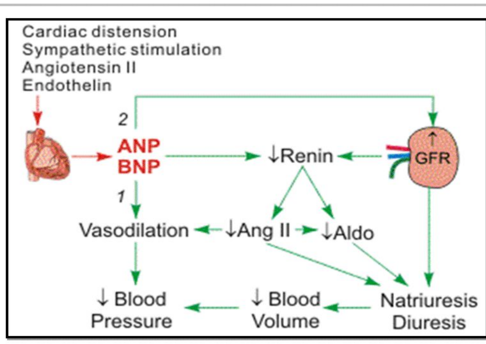
Finding	Sensitivity	Specificity	Positive LR	Negative LR
Symptoms				
Paroxysmal nocturnal dyspnea	0.41	0.84	2.6	0.70
Orthopnea	0.50	0.77	2.2	0.65
Edema	0.51	0.76	2.1	0.64
Dyspnea on exertion	0.84	0.34	1.3	0.48
Fatigue and weight gain	0.31	0.70	1.0	0.99
Cough	0.36	0.61	0.93	1.0
Physical exam				
Third heart sound	0.13	0.99	11	0.88
Abdominal jugular reflux	0.24	0.96	6.4	0.79
JVD	0.39	0.92	5.1	0.66
Rales	0.66	0.78	2.8	0.51
Any murmur	0.27	0.90	2.6	0.81
Lower extremity edema	0.50	0.78	2.3	0.64
SBP <100 mm Hg	0.06	0.97	2.0	0.97
Fourth heart sound	0.05	0.97	1.6	0.98
SBP >150 mm Hg	0.28	0.73	1.0	0.99
Wheezing	0.22	0.58	0.52	1.3
Ascites	0.01	0.97	0.33	1.0

Contrib Nephrol. 2010

Brain Natriuretic Peptide or B-type Natriuretic Peptide



NPs **decrease** blood volume, arterial pressure, CVP, PCWP, and CO.

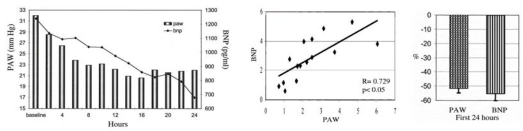


Potential causes of elevated BNP levels

- Cardiac:
  - **Heart failure**
  - Diastolic dysfunction
  - Acute coronary syndromes
  - Hypertension with LVH
  - Valvular heart disease (AS, MR)
  - Atrial fibrillation
- Non-cardiac:
  - Acute pulmonary embolism
  - Pulmonary hypertension (primary or secondary)
  - Sepsis (possibly due to tissue hypoxia or secondary myocardial depression)
  - COPD with cor pulmonale or respiratory failure
  - Hyperthyroidism
  - **Renal failure**

A rapid test for B-type natriuretic peptide **correlates with falling wedge pressures** in patients treated for decompensated heart failure: A pilot study

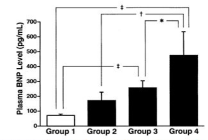
Rapid testing of BNP may be an effective way to improve the in-hospital management of patients admitted with decompensated CHF. Although BNP levels will not obviate the need for invasive hemodynamic monitoring, it may be a useful adjunct in tailoring therapy to these patients.



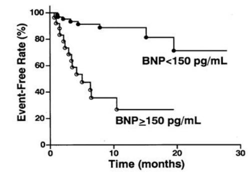
J Card Fail. 2001

Diagnostic and Prognostic Value of Plasma BNP in Non–Dialysis-Dependent CRF

Plasma BNP level as a reliable marker of LV overload, even in non-dialysis patients with CRF. Also, a high BNP level (> or =150 pg/mL) may have powerful predictive potential for heart failure in these patients.

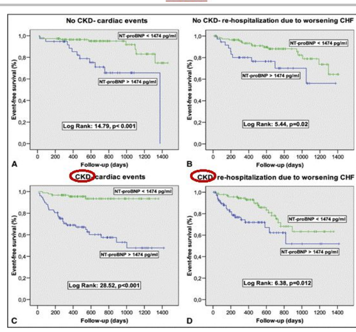


N	53	15	29	6
Preload ↑ Volume	X	O	X	O
Dilatation	X	X	O	O



Am J Kidney Dis. 2004

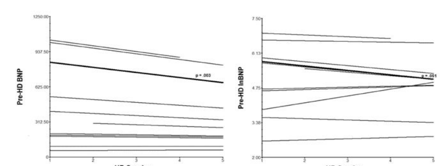
Comparison of the **Prognostic** Usefulness of NT Pro–BNP in Patients With Heart Failure **With** Versus **Without CKD**



Am J Cardiol. 2008

Blood B-Type Natriuretic Peptide and Dialysis

Interdialytic BNP changes are **not related to fluid removed**. Chronic volume overload and increased left ventricular wall tension likely account for the BNP **decrease across dialysis weeks**.

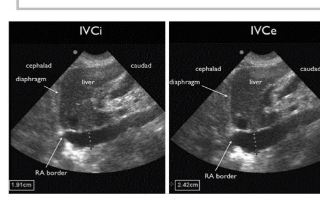


South Med J. 2008

Radiology

- Chest X-Ray
- Thoracic USG: detection of <100 ml amounts of PE
- Echocardiography
- **Respiratory variation of IVC diameter**

Respiratory variation of the IVC diameter (**Caval Index**) reflects the pressure in the RA



IVC Measured	IVC's Percent Collapse during Inspiration	Central Venous Pressure (CVP)
<1.5 cm	>50%	0-5
1.5-2.5	>50%	5-10
1.5-2.5	<50%	10-15
>2.5 cm	Little change	15-20

- Am J Cardiol. 1990 Aug 15;66(4):493-6.
- www.Sonoguide.com/cardiac

IVC normally collapses with inspiration (decreased intra-thoracic pressure) and expands with expiration (but this collapsibility should not exceed 50%)

Caval Index = 100 x (Φ expiration - Φ inspiration)/ Φ expiration

Interpretation: if caval index is greater **than 50%** it suggests low CVP (< 8 mmHg) and high probability of **fluid responsiveness**

Inferior vena cava collapsibility to **guide** fluid removal in slow continuous ultrafiltration

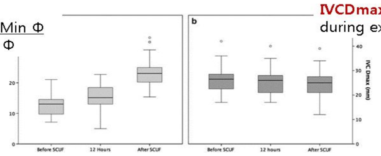
IVC ultrasound is a rapid, simple, and non-invasive means for bedside monitoring of intravascular volume during SCUF and may guide **fluid removal velocity.**

Parameter	Before SCUF (T0)	After SCUF (T2)	*p*
HR (bpm)	82.8 ± 15.7	79.23 ± 12.59	0.425
RR (b/min)	25.9 ± 5.3	22.84 ± 3.36	0.067
MAP (mmHg)	90.6 ± 9.7	86.17 ± 10.33	0.076
Creatinine (mg/dl)	1.7 ± 1.1	1.7 ± 1.3	0.338
Ht (%)	35.7 ± 3.9	37.1 ± 3.5	0.185
$IVCD_{max}$ (mm)	26.0 ± 5.7	24.7 ± 5.9	**<0.048**
IVCCI (%)	12.5 ± 3.6	23.6 ± 5.3	**<0.0001**
pH	7.32 ± 0.06	7.35 ± 0.04	0.982
$PaCO_2$ (mmHg)	56.9 ± 27.5	45.4 ± 17.7	**<0.019**
PaO_2 (mmHg)	65.1 ± 15.4	65.1 ± 14.5	0.656
Arterial lactate (mmol/l)	1.3 ± 0.7	1.3 ± 0.7	0.756

HR heart rate, *RR* respiratory rate, *MAP* mean arterial pressure, *Ht* hematocrit, *$PaCO_2$* partial arterial carbon dioxide pressure, *PaO_2* partial arterial oxygen pressure

IVCCI(%) $= \frac{\text{Max } \Phi - \text{Min } \Phi}{\text{Max } \Phi}$

IVCDmax: maximum Φ during expiration



Intensive Care Med 2010

Respiratory variations of inferior vena cava diameter to **predict** fluid responsiveness in spontaneously breathing patients with acute circulatory failure: **need for a cautious use**

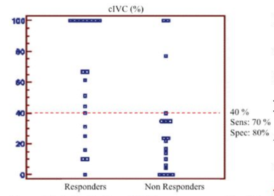


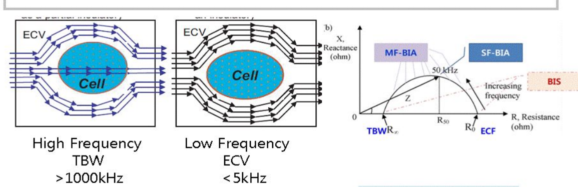
Figure 1 Individual values of inferior vena cava collapsibility (cIVC) (%) after infusion of 500 mL of HES. The best cutoff value is 40%.

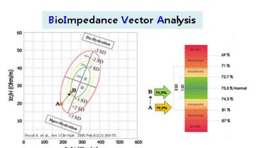
Response to fluid challenge was defined as a 15% increase of subaortic velocity time index (VTI) measured by TTE.

In spontaneously breathing patients with ACF, high cIVC values (>40%) are usually associated with fluid responsiveness, **while low values (<40%) do not exclude fluid responsiveness.**

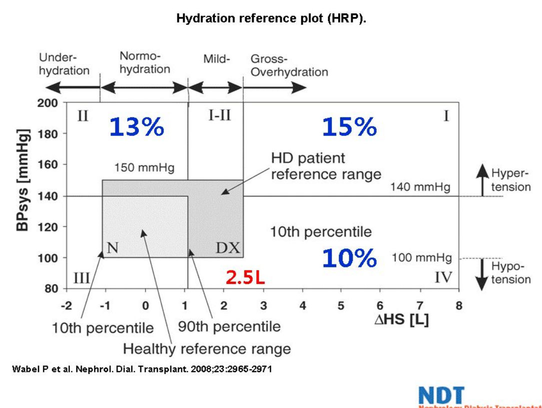
Crit Care, 2012

Principles of bioimpedance analysis (BIA)



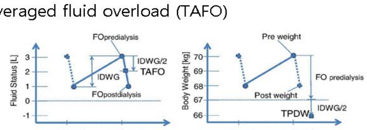


Seminars in Dialysis, 2012



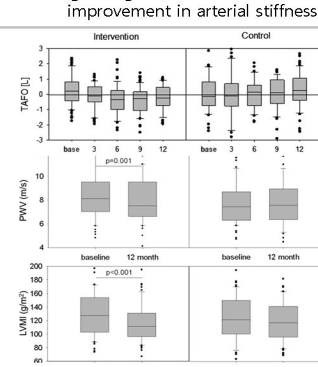
Effect of Fluid Management Guided by Bioimpedance **Spectroscopy** on Cardiovascular Parameters in Hemodialysis Patients : A Randomized Controlled Trial

- Intervention group(n=78), FO information was **provided** to treating physicians and used to adjust fluid removal during dialysis.
- Control group(n=78), FO information was **not provided** to treating physicians and fluid removal during dialysis was adjusted according to usual clinical practice.
- Time-averaged fluid overload (TAFO)



Am J Kidney Dis, 2013

Assessment of FO with BIS provides better management of fluid status, leading to regression of LVMI, decrease in BP, and improvement in arterial stiffness



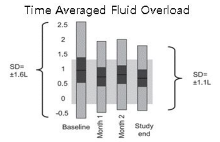
Am J Kidney Dis, 2013

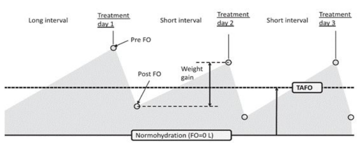
Bioimpedance-guided fluid management in hemodialysis patients

55 chronic HD patients over 3months.

A target range of 0.56±0.75L

1. TAFO>2.8 L: decrease postweight by 1 kg/wk.
2. TAFO between 1.25 and 2.8 L: decrease postweight by 0.5 kg/wk.
3. TAFO between −0.25 and 1.25 L (on target): maintain current dry weight prescription.
4. TAFO<−0.25 L: increase postweight by 0.5 kg/wk.

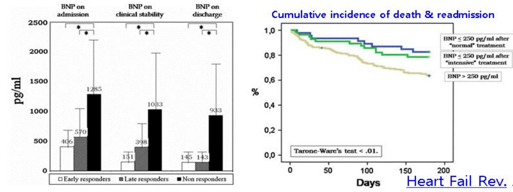




Clin J Am Soc Nephrol. 2013

Optimizing fluid management in patients with ADHF: the emerging role of combined measurement of BIVA and BNP levels

- N=300
- **Therapy was titrated to reach a BNP value of 250 pg/ml**, whenever possible. Patients were categorized as early responders (rapid BNP fall below 250 pg/ml); late responders (slow BNP fall below 250 pg/ml, after aggressive therapy); and non-responders (BNP persistently 250 pg/ml).



Heart Fail Rev. 2011

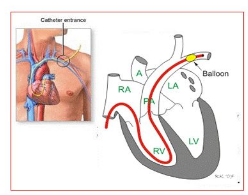
NON-INVASIVE Methods to assess ECV volume

Technique	What is measured	Advantage	Limitation
Tracers	TBW, ECW	Reference method Absolute volume attained	Invasive, cost, Specially trained staff required Time cost Tracers enter the cells cannot assess patient's fluid status
BIA	TBW, ECV, ICV	Noninvasive, easy to use, Quantifies and measures change in fluid volume determines body composition, Fluid status reproducibility	Accurate measurement influenced by skin, body position, and composition No uniform standard for different devices
RBV	BV	Noninvasive, ease of use Real-time monitoring of BV change, reproducibility	No absolute BV and ECV Only measures relative blood volume change Influenced by ultra-filtration rate and other physiological mechanisms, such as sympathetic nervous system
IVCD	BV	Noninvasive Strong correlation with right-sided heart failure	No absolute BV and ECV Only measures relative blood volume change Inter-operator error
Biomarker (pro-BNP, BNP)	BV	Noninvasive	No absolute BV and ECV Only measures relative volume change Wide variability

TBW, total body water; ECV, extracellular fluid; ICV, intracellular fluid; RBV, relative blood volume; BV, blood volume; IVCD, diameter of the inferior vena cava.

Seminars in Dialysis, 2012

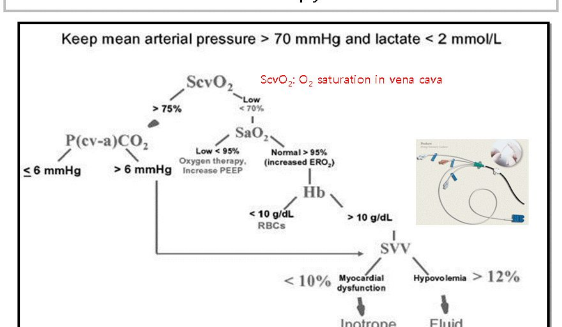
Invasive Monitoring



- CO= BP/PR
- Filling pressure

- In hemodynamically unstable patients not responding to traditional treatments
- Who are refractory to initial therapy
- Who have a combination of congestion and hypoperfusion
- Whose volume status and cardiac filling pressures are unclear
- Who have clinically significant hypotension and worsening renal function during therapy

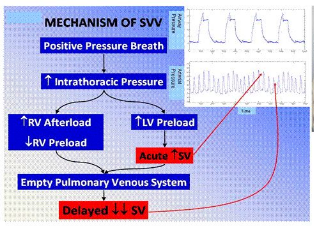
Tissue Oxygenation Parameters to Guide Fluid Therapy

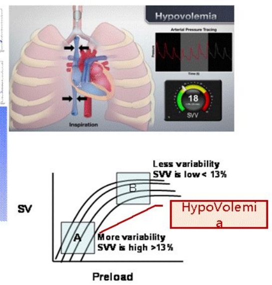


Arterial preload responsiveness parameters

History of preload responsiveness parameters		
Category	Parameter	Used from
Static parameters	**CVP**	1960's
	PCWP	1970's to date
Effective Fluid Monitoring Requires Preload responsiveness and **stroke volume response**		
Preload responsiveness	**Manual** calculation of arterial line "pulsus paradoxus" (**SPV**)	1960's
Dynamic preload parameters: and Stroke volume response	**Automated** reporting : Systolic pressure variation, Pulse pressure variation & Stroke volume variation (**SPV, PPV & SVV**)	2000 to date

Stroke Volume Variation

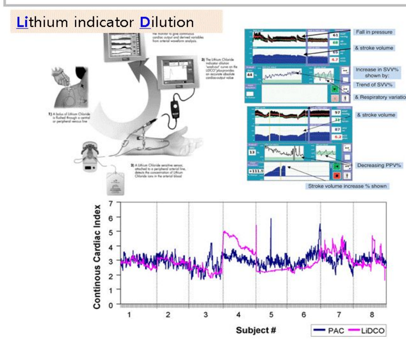




$$\%SVV = \frac{SV\ max - SV\ min}{SV\ mean}$$

Stroke Volume Variation-guided fluid therapy and oximetric guidance. LiDCO/PulseCO system

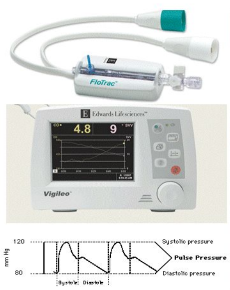
Lithium indicator Dilution



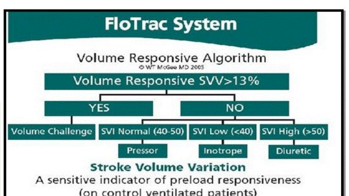
When coupled with non-invasive pulse oximetry, it can also give total body O_2 delivery (DO_2) and consumption (VO_2).

Resuscitation. 2009

Stroke Volume Variation-guided fluid therapy Flotrac-Vigileo system



Unlike PiCCO/PulseCO/LiDCO, it does not require external calibration, or the presence of a central line or specialized catheter.



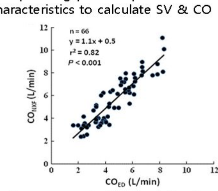
Vigileo Monitor Hemodynamic Parameters

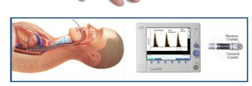
Parameter	Normal Range
CO (Cardiac Output)	4.0 - 8.0 L/min
CI (Cardiac Index)	2.5 - 4.0 L/min/m²
SV (Stroke Volume)	60 - 100 mL/beat
SVI (Stroke Volume Index)	33 - 47 mL/beat/m²
SVR (Systemic Vascular Resistance)	800 - 1200 dynes - sec/cm⁵
SVRI (Systemic Vascular Resistance Index)	1970-2390 dynes - sec/cm⁵/m²
SVV (Stroke Volume Variation)	<15%
ScvO2	≥70%

Comparison of **noninvasive cardiac output** measurements using the Nexfin monitoring device and the esophageal Doppler

Volume-clamp method

The area under the systolic part of the blood pressure waveform as input into an algorithm incorporating patient-specific aortic vascular characteristics to calculate SV & CO





There was a significant relationship between CO_{ED} and CO_{NXF} (r2 = 0.82; P<0.001). The agreement between CO_{ED} and CO_{NXF} was 0.88 ± 0.86 L/min (Bland Altman).

J Clin Anesth. 2012

Summary in Fluid management

- **Early protocol-designed fluid resuscitation** may prevent the occurrence of AKI, particularly in patients with severe sepsis and septic shock.
- The preferred evidence based resuscitation fluid is a **crystalloid** solution.
- Persistent **fluid overload** in AKI patients may lead to hypoxia, mechanical ventilation, ARDS, and increased mortality.

Summary in Fluid management

- **Diuretics** should be used in patients with AKI in the ICU for the **management of the volume overload**, **rather than just for converting** patients from oliguric to nonoliguric AKI.
- **Both BNP and BIA** are potential methods of assessing fluid status in HD patients.
- **SVV and PVV** measured by minimally invasive monitoring system can predict fluid responsiveness in critically ill patients.

CONCLUSION

- Once AKI occurs and that hemodynamic status is stabilized, the relevance of restrictive fluid management and the use of diuretics or renal replacement therapy to prevent or treat fluid overload improve outcomes.
- Critically ill patients have some benefits from a carefully monitored fluid regimen based on individualized goal-directed therapy.