

Fluid selection and management

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Outlines

➤ Introduction of **Fluid**

➤ **Fluid** selection

➤ **Fluid** management

Introduction of fluid

Fluid= **water** + ?

Crystalloid solution = **water** + electrolytes

Colloid solution =

water + electrolytes + large molecular substance

Parenteral nutrition=

water + electrolytes + nutrient (glucose/amino acid/lipid etc.)

Fluid Therapy

Maintenance

replaces losses of **water** and **electrolytes**
under **normal physiologic conditions** via
urine, sweat, respiration, and stool

Replacement

corrects **water** and **electrolyte** deficits
result from **GI, urinary, or skin losses, bleeding,**
third-space sequestration, and relative hypovolemia etc.

Replacement Fluid Therapy

Goal

Correct abnormalities in volume status & serum electrolytes

No formula accurately estimate the total fluid deficit

Too little (Not enough)

Reduced effective circulating volume

Diversion of blood flow away from gut, kidney etc

Too much

Increasing loss to extracellular space

Pulmonary, peripheral and gut wall edema

How much fluid?

Absolute Hypovolemia

Relative Hypovolemia (Severity of inflammation)

History:
intake/loss, use of diuretics

Fever/chills

**Consider albumin level,
check skin turgor, appearance
(dry ? edema ? chemosis ?)**

WBC/Band%

BUN/Cr. ratio

Platelet/DIC

HCO₃⁻ conc., Na⁺

CRP, PCT

Everyday

Hemodynamic Status

+

Hemodynamic Support if necessary

Fluid Status

+

Fluid Management if necessary

Hemodynamic Status

Perfusion pressure ?

Perfusion ? (Flow, Cardiac output) ?

Oxygen delivery (C.O, Hb, SaO₂) ?

= (Cardiac output) × (O₂ content) × 10

Intravascular volume ?

Fluid Status

Internal human body

Pulmonary edema

Pulmonary congestion

Pleural effusion

Ascites

Bowel edema

External human body

Sclera

Scalp

Trunk

Limbs

Inner side of thigh

Genital area

**hydrostatic pressure \uparrow or permeability \uparrow or oncotic pressure \downarrow
or Mixed**

Goal of Hemodynamic Support

Adequate **perfusion pressure**

Adequate **perfusion (Q, cardiac output)**

Adequate **O₂ delivery (Q, Hb, SaO₂)**

= (Cardiac output × O₂ content)

= (**SV** × **HR**) × [(1.34 × **Hb**) **SaO₂** + 0.003 PaO₂]

Based on Adequate Intravascular Volume

2001 EGD T – 2012 S.S.C

2001 EGD T

MAP \geq 65 mmHg

U/O \geq 0.5 ml/kg/hour

ScvO₂ \geq 70%

CVP \geq 8-12 mmHg

N Engl J Med 2001;345:1368-77.

2004 Surviving Sepsis Campaign

Central venous pressure: 8–12 mm Hg

Mean arterial pressure \geq 65 mm Hg

Urine output \geq 0.5 mL·kg⁻¹·hr⁻¹

Central venous (superior vena cava) or mixed venous oxygen saturation \geq 70%

Grade B

2008 Surviving Sepsis Campaign

Central venous pressure (CVP): 8–12 mm Hg

Mean arterial pressure (MAP) \geq 65 mm Hg

Urine output \geq 0.5 mL·kg⁻¹·hr⁻¹

Central venous (superior vena cava) or mixed venous oxygen saturation \geq 70% or \geq 65%, respectively (Grade 1C)

2012 Surviving Sepsis Campaign

a) CVP 8–12 mm Hg

b) MAP \geq 65 mm Hg

c) Urine output \geq 0.5 mL·kg·hr

d) Superior vena cava oxygenation saturation (ScvO₂) or mixed venous oxygen saturation (SvO₂) 70% or 65%, respectively.

Importance of **Perfusion Pressure**

Brain

$$\text{CPP} = \text{MAP} - \text{ICP}$$

Heart

$$\text{Coronary perfusion pressure} = \text{DBP} - \text{LVEDP}$$

Kidney

$$\text{Glomerular filtration pressure} =$$

(Glomerular hydrostatic pressure – oncotic pressure)

– Bowman's capsule hydrostatic pressure

Importance of Oxygen Delivery

VO_2 (O_2 uptake) < MRO_2 (metabolic requirement for O_2)

Oxygen debt $\uparrow\uparrow$ Anaerobic metabolism $\uparrow\uparrow$

VO_2 : oxygen uptake = $\text{C.O} \times (\text{CaO}_2 - \text{CvO}_2) \times 10$

CaO_2 = O_2 content in **arterial blood**

CvO_2 = O_2 content in **mixed venous blood**

Aerobic metabolism:

1 mole glucose

36 ATP (673 Kcal)

Anaerobic metabolism:

1 mole glucose

2 ATP (47 Kcal)

Fluid Selection in Hemodynamic Support

Fluid = **water** + ?

Crystalloid or Colloid ?

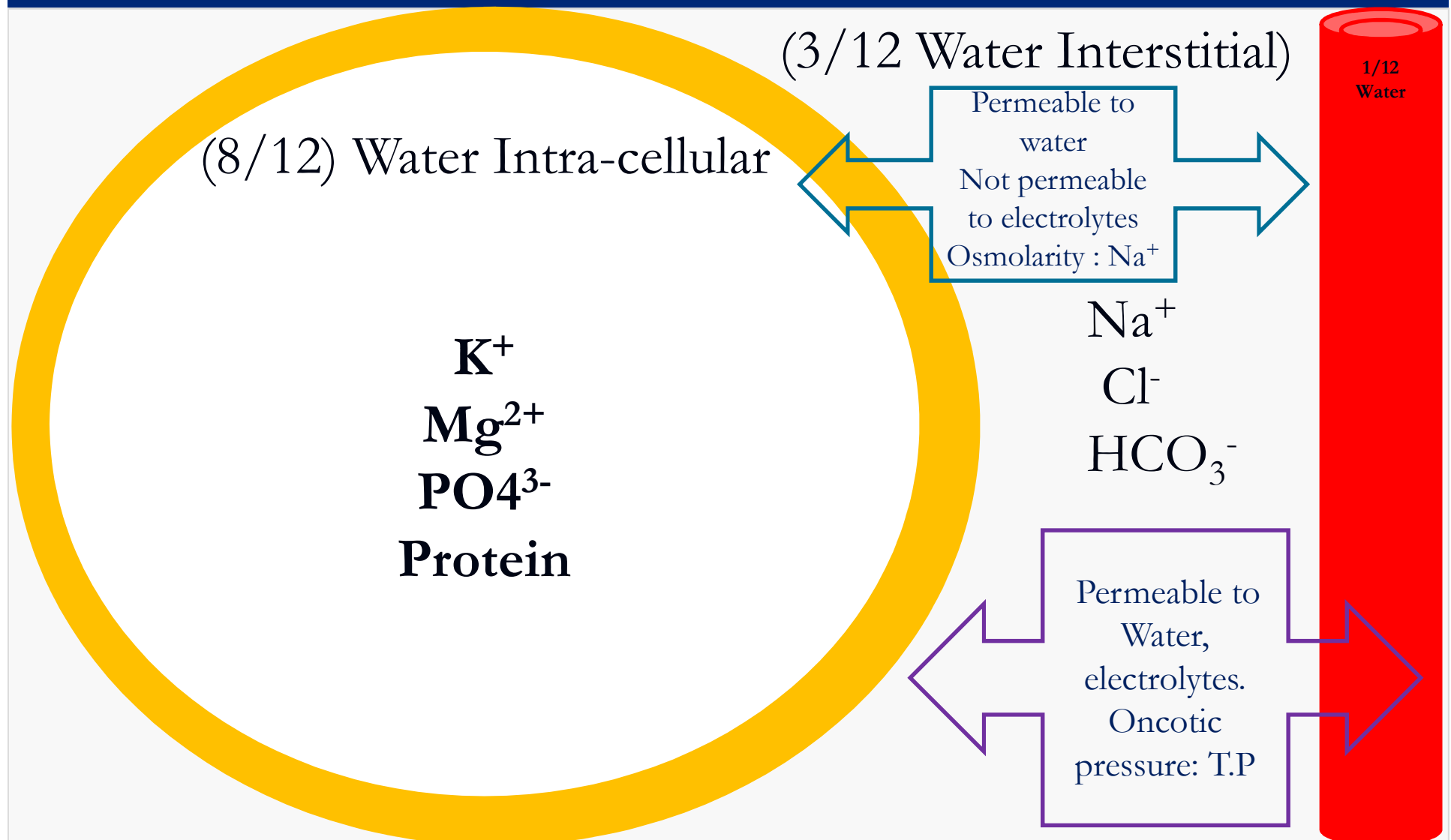
No definite recommendation in resuscitation

In most conditions, **crystalloid worked well**

Colloid may be **more efficient** when

large volume resuscitation **required**

Fluid (Water) distribution



Fluid Composition (1)

	Na^+	K^+	Mg^{++}	Ca^{++}	Cl^-	PH
Plasma	140	4	2	5	103	7.4
0.9 % N/S	154	0	0	0	154	5.7
L.R	130	4	0	3	109	6.4

Fluid Composition (2)

	Na ⁺	K ⁺	Mg ⁺⁺	Cl ⁻	PH	Oncotic Pressure
Plasma	140	4	2	103	7.4	20-25
Voluven	154	0	0	154	4.0-5.5	36
Volulyte	137	4	1.5	110	5.7-6.5	36
5% Albumin	145 ±15	≤ 2	0	145±15	6.4-7.4	20
25% Albumin	145 ±15	≤ 2	0	145±15	6.4-7.4	70

Water Distribution

<p>1L N/S</p>	<p>Interstitial (750 ml) Intravascular (250 ml)</p>
<p>1L Ringer's Lactate</p>	<p>Interstitial (750 ml) Intravascular (250 ml)</p>
<p>1 L D5W</p>	<p>2/3 Intracellular (667 ml) 1/3 Extracellular (333 ml) 3/4 (250 ml) interstitial 1/4 (83.3 ml) intravascular</p>
<p>1L 0.45% G/S = 0.5 L N/S + 0.5 L D₁₀W</p>	<p>Intracellular (333 ml) Interstitial (500 ml) Intravascular (1.5 + 0.5) 83.3 ml</p>

2012 Surviving Sepsis Campaign Strong Recommendation

Against hydroxyethyl starches (HES) for fluid resuscitation
of **severe sepsis** and **septic shock** (grade 1B)

Trials

WISEP

CRYSTMAS

6S

CHEST

Surviving Sepsis Campaign

2008 → 2012

E. Fluid Therapy (2008 Surviving Sepsis Campaign)

1. We recommend fluid resuscitation with either natural/artificial colloids or crystalloids. There is no evidence-based support for one type of fluid over another (Grade 1B).

G. Fluid Therapy of Severe Sepsis (2012 Surviving Sepsis Campaign)

1. We recommend crystalloids be used as the initial fluid of choice in the resuscitation of severe sepsis and septic shock (grade 1B).
2. We recommend against the use of hydroxyethyl starches (HES) for fluid resuscitation of severe sepsis and septic shock (grade 1B). (This recommendation is based on the results of the VISEP [128], CRYSTMAS [122], 6S [123], and CHEST [124] trials.

Mechanism of HES-related kidney injury

Hyperoncotic kidney failure

GFR ↓ secondary to **filtration fraction** ↓

Tubular obstruction and medullary ischemia

accumulation of filtered colloid molecules (**direct toxicity**)

Osmotic nephrosis

a structural change in renal proximal tubular cells

vacuolization of proximal tubular cells

Determinants of the GFR (1)

$$\text{GFR} = K_f \times \text{Net filtration pressure}$$

K_f

glomerular capillary filtration coefficient

Net filtration pressure

hydrostatic + colloid osmotic forces
across glomerular membrane

$$\text{Net filtration pressure} = P_G - P_B - \pi_G + \pi_B$$

$$\text{GFR} = K_f \times (P_G - P_B - \pi_G + \pi_B)$$

Determinants of the GFR (2)

$$\text{Net filtration pressure} = P_G - P_B - \pi_G + \pi_B$$

P_G hydrostatic pressure inside glomerular capillaries, \uparrow filtration

P_B hydrostatic pressure in Bowman's capsule, \downarrow filtration

π_G colloid osmotic pressure of glomerular capillary, \downarrow filtration

π_B colloid osmotic pressure of glomerular capillary plasma proteins, considered zero

$$\text{GFR} = K_f \times (P_G - P_B - \pi_G + \pi_B)$$

Determinants of the GFR (3)

Glomerular capillary colloid osmotic pressure \uparrow – **GFR** \downarrow

Glomerular capillary colloid osmotic pressure influenced by

- **arterial plasma colloid osmotic pressure**
- **fraction of plasma filtered by glomerular capillaries**

(filtration fraction), increasing filtration fraction also concentrates plasma proteins and raises glomerular colloid osmotic pressure

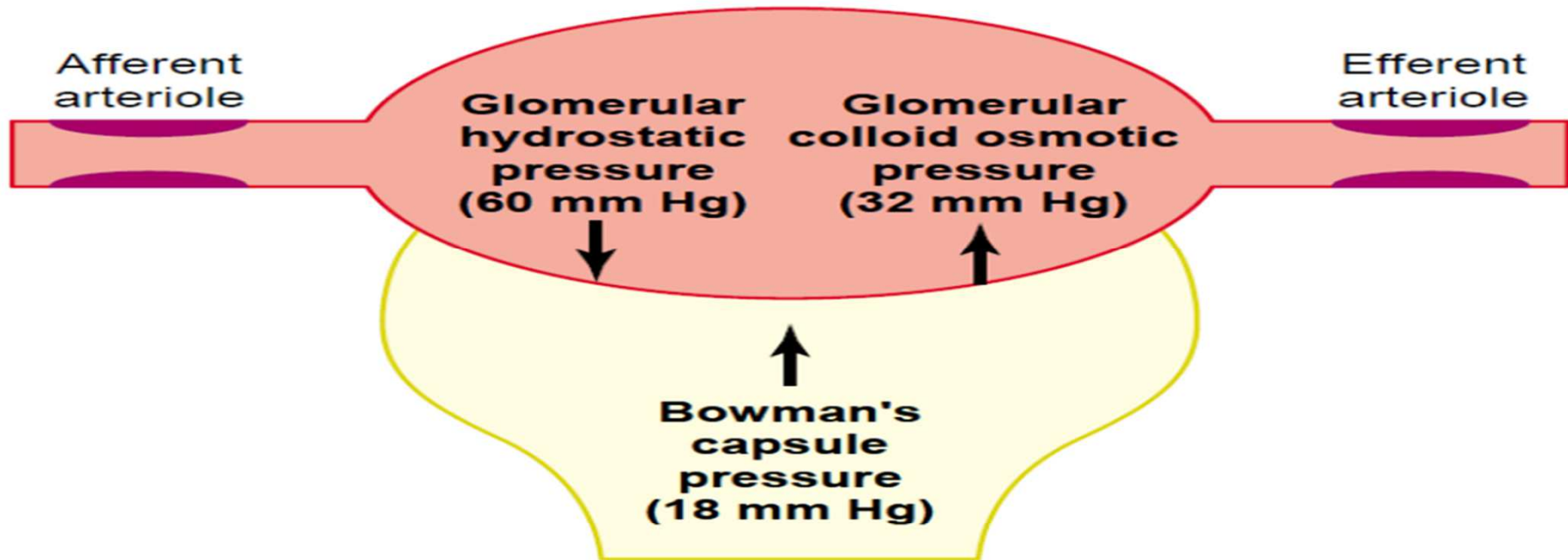
Hyperoncotic Renal Failure

Occurs with **all hyperoncotic colloids**

Inadequate crystalloid administration

Occurs in **dehydrated** patients given large volumes of hyperoncotic solutions

Believe ? Like ? Oncotic pressure ?



$$\text{Net filtration pressure (10 mm Hg)} = \text{Glomerular hydrostatic pressure (60 mm Hg)} - \text{Bowman's capsule pressure (18 mm Hg)} - \text{Glomerular oncotic pressure (32 mm Hg)}$$

**Don't like low oncotic edema.
Avoid potential high oncotic renal failure.**

Tubular Obstruction

Precipitation of particles in tubules

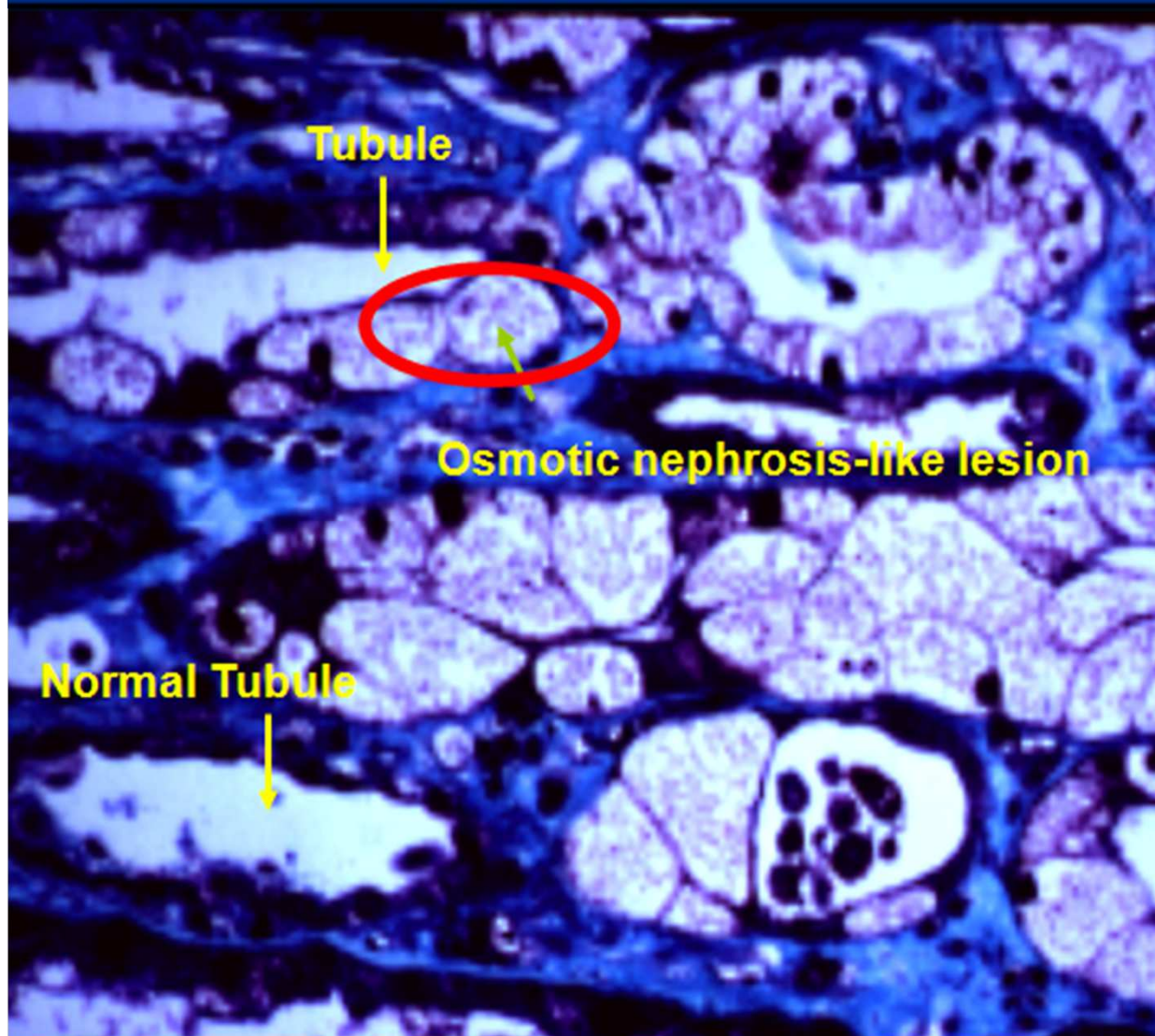
Tubular **accumulation** of particles

Tubular **obstruction** responsive to diuretic therapy

Possible tubular uptake and direct toxicity

Only described with dextrans

Osmotic Nephrosis



Reported with **all colloids** including albumin, mannitol, hypertonic glucose

Significance?

2012 CRYSTMAS

Effects of Voluven on Hemodynamics and Tolerability of Enteral Nutrition in Patients With Severe Sepsis
(**CRYSTMAS**): 2007-2012

RESEARCH

Open Access

Assessment of hemodynamic efficacy and safety of 6% hydroxyethylstarch 130/0.4 vs. 0.9% NaCl fluid replacement in patients with severe sepsis: The CRYSTMAS study

Guidet et al. Critical Care 2012, 16:R94

2012 CRYSTMAS

Prospective, multicenter, active-controlled,
double-blind, randomized study in ICU

Severe sepsis patients received
6% HES 130/0.4 (**colloid treatment group**) or
Sodium chloride (NaCl 0.9%) (**crystalloid control group**)
Maximum allowed dose: 50 ml/kg/day on 1st day and
25 ml/kg/day from the 2nd -4th day.
Extra fluid: crystalloids (with no volume limitation).

Primary end points

Amount of study drug to achieve initial **HDS** (hemodynamic stabilization)
HDS: MAP \geq 65 mmHg, and at least two of (maintained for 4 hours)
CVP between 8-12 mmHg, U/O $>$ 2 ml/kg/hr, or ScvO₂ \geq 70 %

2012 CRYSTMAS

Results

Significantly less HES to reach HDS vs. NaCl ($1,379 \pm 886$ ml in HES group and $1,709 \pm 1,164$ ml in NaCl group ($P = 0.0185$))

No difference between AKIN and RIFLE among groups and no difference in mortality, coagulation, or pruritus up to 90 days.

Conclusion

Significantly **less volume to achieve HDS for HES** in initial phase of fluid resuscitation in severe sepsis and **without any difference for adverse events.**

However

No difference for adverse events, No difference in mortality

2012 CRYSTMAS

Materials and methods

Study design

This prospective, multicentre, active-controlled, double-blind, randomized, clinical study conducted in France and Germany enrolled patients suffering from severe sepsis. Patients received either 6% HES 130/0.4 (colloid treatment group) or sodium chloride (NaCl 0.9%) (crystalloid control group), hereafter referred to as the HES and NaCl groups. The maximum allowed dose for both treatment groups was 50 ml/kg/day ($\leq 8 \times 500$ ml bags/day for patients weighing ≥ 80 kg) on the first day and 25 ml/kg/day ($\leq 4 \times 500$ ml bags/day for patients weighing ≥ 80 kg) from the second to the fourth day. If extra fluid was required beyond this daily volume and four-day time period, fluid resuscitation was to be carried out using intravenously administered crystalloids (with no volume limitation).

The investigational and control drugs were identical in appearance and packaging, and were labeled with randomization numbers (20 bags per randomization number) using a blinding methodology as previously described [9]. In order to ensure sufficient hydration, additional crystalloid infusions were requested and given in a ratio to study medication of 1:2. The patient flow of the study is summarized in Figure 1.

2012 CRYSTMAS

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Adequate crystalloid provision in HES. before HES?

Revisit 2012 Surviving Sepsis Campaign

May say

G. Fluid Therapy of Severe Sepsis

1. We recommend crystalloids be used as the initial fluid of choice in the resuscitation of severe sepsis and septic shock (grade 1B).
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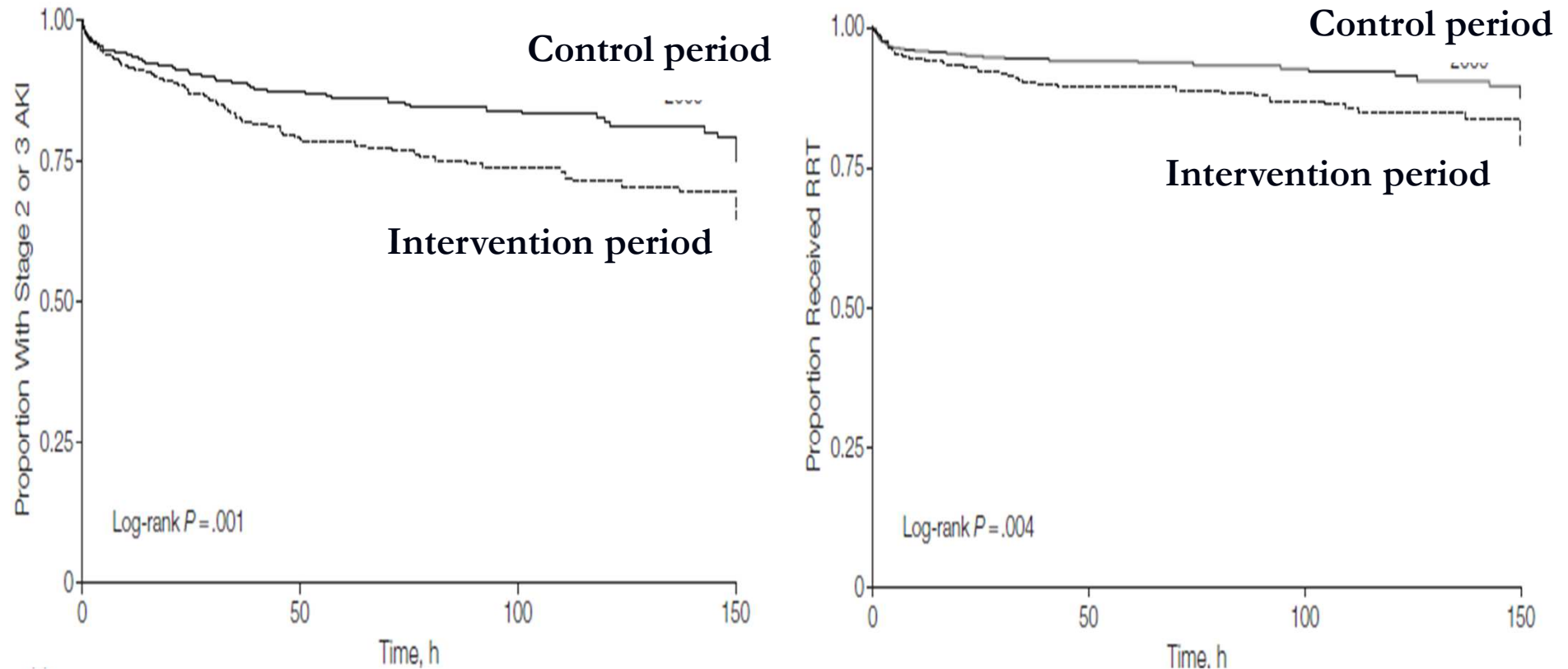
2012 CHLORIDE

Chloride **H**igh **L**evel **O**f **R**esuscitation **I**nfusion
Delivered **E**valuation (**CHLORIDE**): 2008-2009

**Association Between a Chloride-Liberal
vs Chloride-Restrictive Intravenous Fluid
Administration Strategy and Kidney Injury
in Critically Ill Adults**

JAMA. 2012;308(15):1566-1572

2012 CHLORIDE



Conclusion

Chloride-restrictive strategy associated with a **significant decrease** in the incidence of **AKI** and use of **RRT**.

High **CHLORIDE** Also Not Good

Renal vasoconstriction

May activate tubuloglomerular feedback,
trigger afferent arteriolar vasoconstriction,
mesangial contraction, and
associated **reductions in GFR**

Chloride infusion may induce
thromboxane release with associated **vasoconstriction**

Now

No ideal solution !

Fluid choice: **Crystalloid** or **Colloid**?

Hydrated status	Albumin level	Na⁺	Crystalloid
Dehydrated	Chemosis	Na ⁺	0.9% N/S
Normal hydrated	Peripheral edema	K ⁺	Lactated Ringer's
Edematous	Permeability ?	Cl ⁻	Colloid

Fluid Management

I/O positive \neq positive balance

I/O negative \neq negative balance

Always I/O positive balance **not reasonable**

Always I/O negative balance **not reasonable**

水腫

微血管內外水份的移動：

請把微血管想像成一條週邊建有河堤的河川

水位高漲時

hydrostatic pressure ↑

河堤的高度下降

oncotic pressure ↓

河堤的結構完整性受損

capillary permeability ↑

水(微血管內的水)都想由內往外流-- 形成水腫(淹水)

Negative Fluid Balance (1)

1. Internal or External fluid overload (+)

---- Minimize maintenance fluid

NG feeding absorption - full, no maintenance fluid

No diarrhea, NG feeding fluid restriction: **2 Kcal/ml**

Beware of beginning **Na, K, HCO₃⁻**

Negative Fluid Balance (2)

2. Consider hemodynamics & current SIRS

Adequate perfusion pressure: $\text{MAP} \geq 60\text{-}65$ mmHg

Adequate perfusion:

$\text{C.I} \geq 2.5$ or warm peripheral perfusion,

no mottled skin, capillary refill < 2 seconds

No evidence of organ under-perfusion after I/O negative

Inflammatory parameters

(Temp./WBC/band/Platelet/CRP/PCT. etc. improving trend)

Negative Fluid Balance (3)

3. Consider heart, kidney, oncotic pressure & SIRS again

SIRS severity ?

LV and renal function ?

Total protein and oncotic pressure ?

- Landis and Pappenheimer equation:

* Estimated **COP** = $2.1(\text{TP}) + 0.16(\text{TP})^2 + 0.009(\text{TP})^3$

謝謝指教！