What's in water

An Overview of Intravenous Fluid Therapy

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- Body fluid compartment
- Daily fluid and electrolyte requirements for an average adult
- Major components of replacement fluid
- Maintenance vs. Resuscitation
- Complications of fluid therapy

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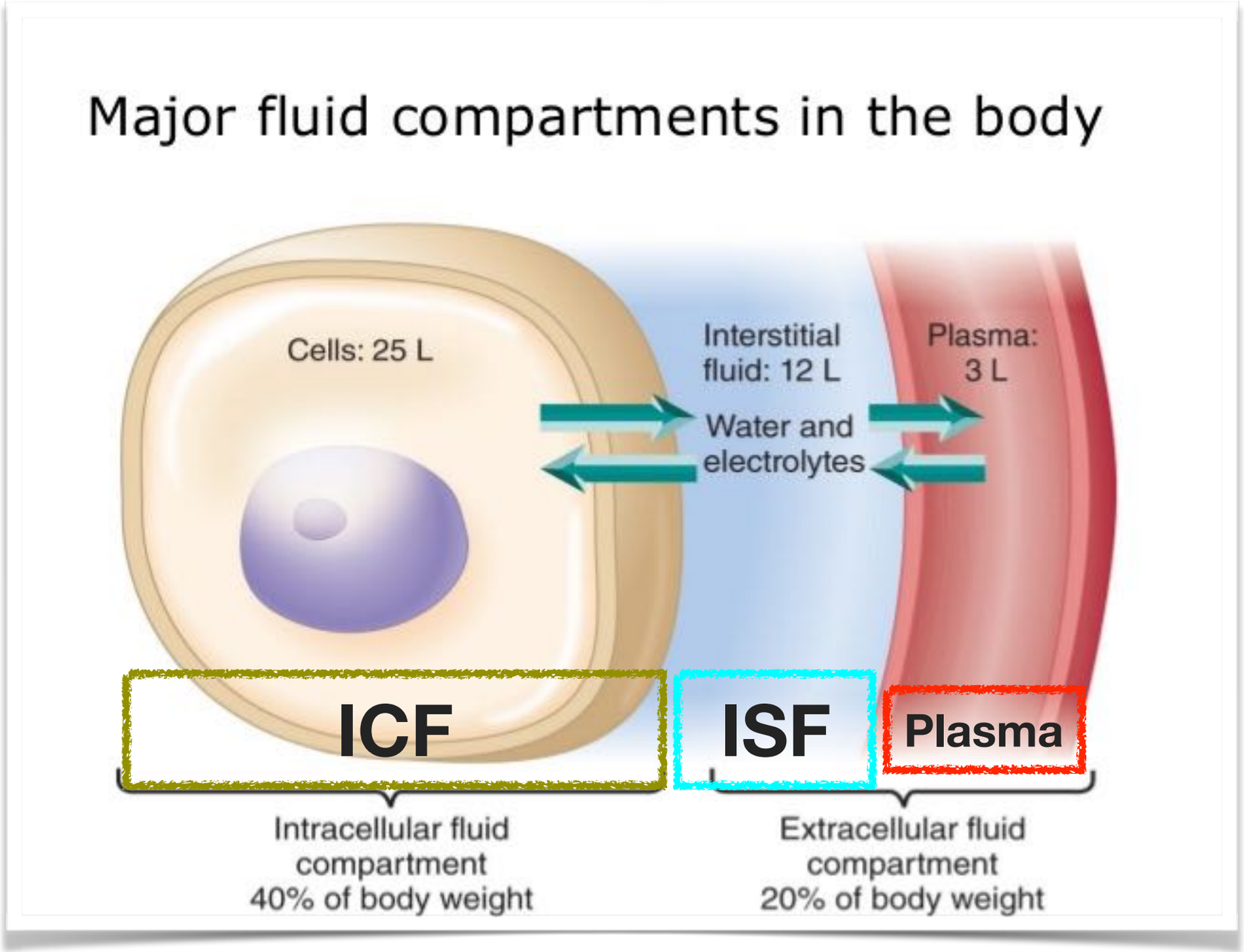
Major fluid compartment of the body: adult 70kgs



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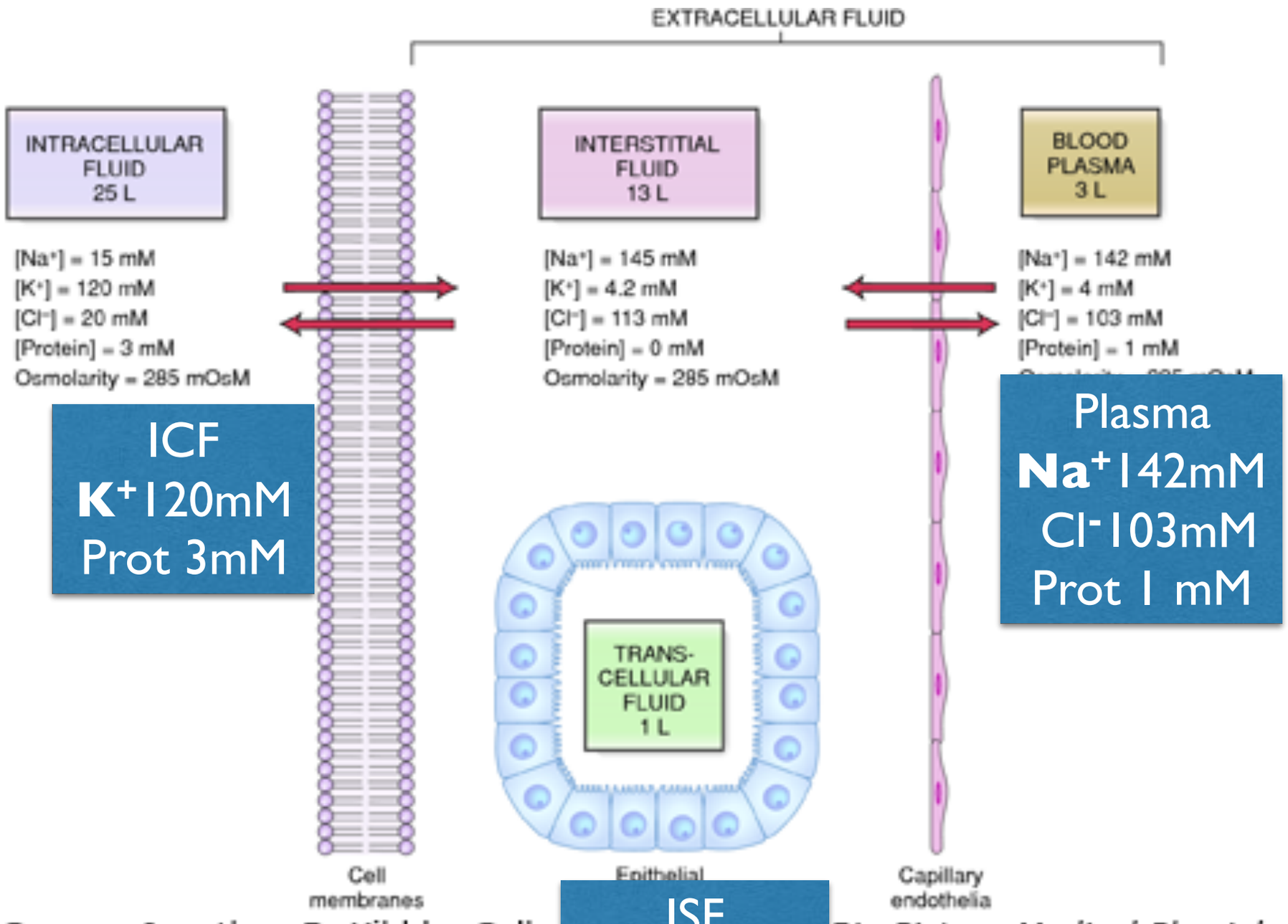
Electrolyte in body compartment



ICF
K^+120mM
Prot 3mM

Plasma
Na^+142mM
Cl^-103mM
Prot 1 mM

ISF
Na^+145mM
Cl^-113mM

Source: Jonathan D. Kibble, Colby … *Big Picture Medical Physiology*: www.accessphysiotherapy.com

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WATER BALANCE

The balance between intake and excretion of fluids.

Thirst

Am I in Water Balance?

When the body is in water balance
the input and output of water are equal

WATER INTAKE FROM:

Aproximate values

- Fluids: 1,200 ml/day
- Foods: 1,000 ml/day
- Metabolically produced: 300 mL/day

2,500 ml/day

WATER OUTPUT FROM:

Aproximate values

- Insensible: 700 ml/day
- Sweat: 100 ml/day
- Feces: 200 ml/day
- Urine: 1,500 ml/day

2,500 ml/day

Hypertonicity:hypothalamus
Hypovolemia,Hypotension:Baroreceptor
RAS:Renal hypotension

THIRST

Thirst is "the physiological urge to drink water"

The 4 major stimuli to thirst are:

Hypertonicity: Cellular dehydration acts via an osmoreceptor mechanism in the hypothalamus
Hypovolaemia: Low volume is sensed via the low pressure baroreceptors in the great veins and right atrium
Hypotension: The high pressure baroreceptors in carotid sinus & aorta provide the sensors for this input
Angiotensin II: This is produced consequent to the release of renin by the kidney (eg in response to renal hypotension

legroj.org

Simplicity is the major feature needed in physiological basic concepts.

Contents of IV Fluid Preparations

	Na (mEq/L)	K (mEq/L)	Cl (mEq/L)	HCO3 (mEq/L)	Dextrose (gm/L)	mOsm/L
Plasma	140	4	109	24	1000	285-295
D5W					50	278
½ NS	77		77			143
D51/2NS	77		77		50	350
NS	154		154			286
D5NS	154		154		50	564
Ringers Lactate/ Acetate	130	4	109	28		272

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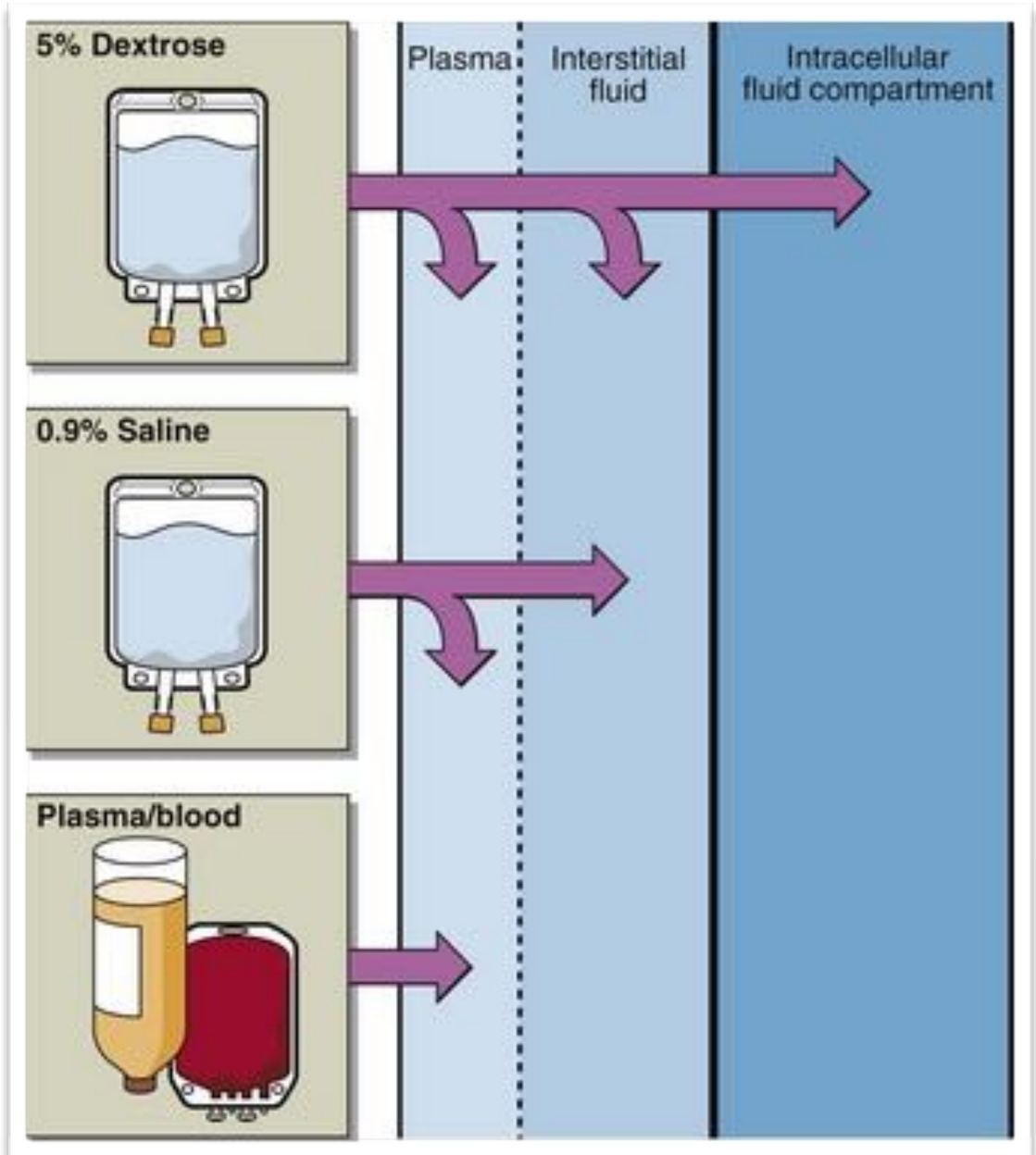
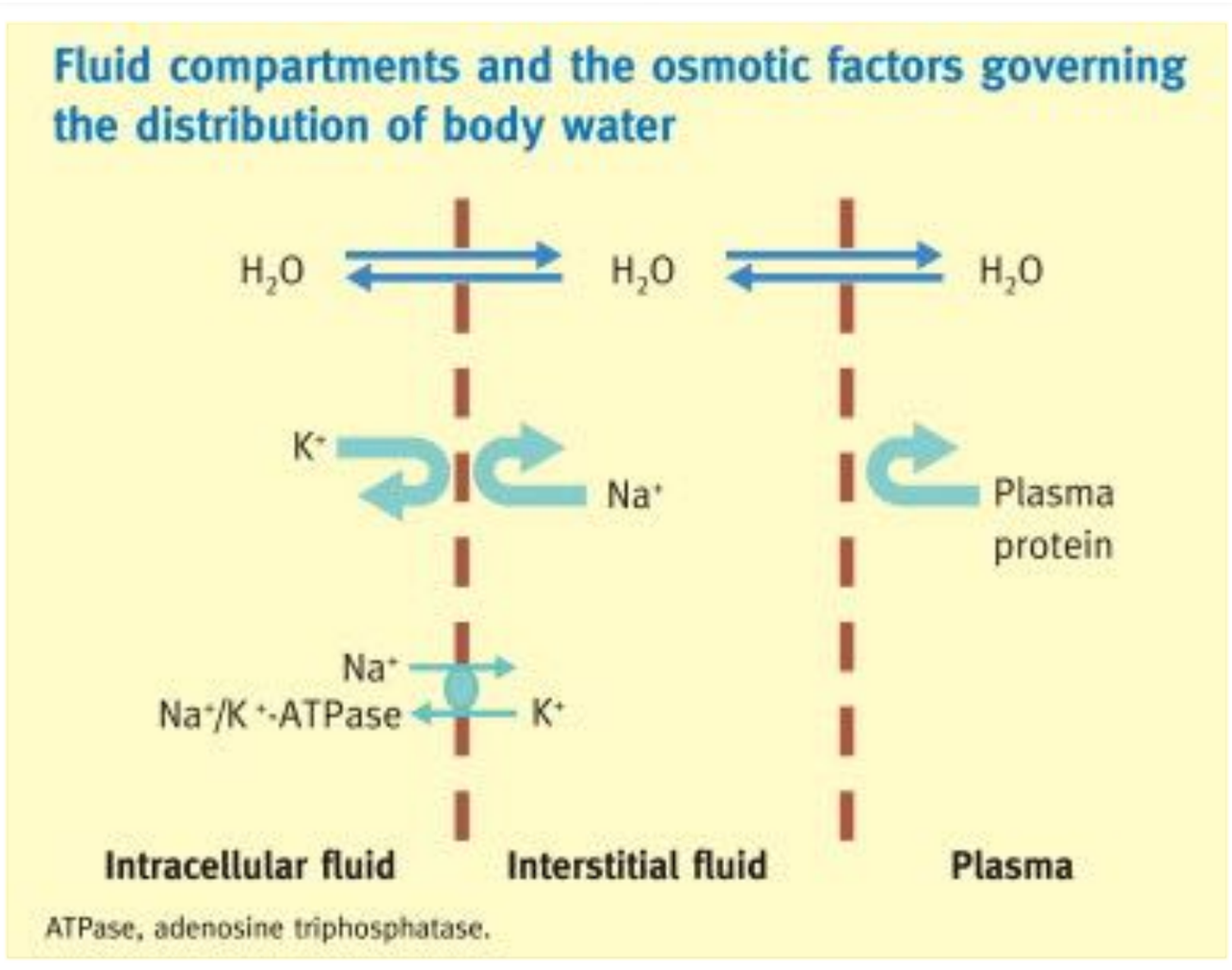
Which fluid?


5% Dextrose
0.9% Saline
Plasma/blood
Plasma
Interstitial fluid
Intracellular fluid compartment


Fluid compartments and the osmotic factors governing the distribution of body water
H2O
H2O
H2O
K+
Na+
Plasma protein
Na+
Na+/K+-ATPase
K+
Intracellular fluid
Interstitial fluid
Plasma
ATPase, adenosine triphosphatase.

Major aspects consideration of volume replacement therapy

- Maintenance : Deficit : Resuscitation
- The type of fluid?
- The amount of fluid?
- The criteria for guiding volume therapy
- Possible side effects
- Costs

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Maintenance Therapy

- Determine the appropriate rate:

1) Calculate maintenance based on average requirement of 35 cc/kg/day

2) “4/2/1” rule = ml/hr

   4 ml/kg/hr for the first 10 kg (0-10kg)

   2 ml/kg/hr for the next 10kg (11-20kg)

   1 ml/kg/hr for remaining weight (21 kg and up)

3) Weight in kg + 40 = ml/hr

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Daily Electrolyte Requirements

- Sodium: 100-250meq
  mostly excreted in urine
- Potassium: 50-100meq
  mostly excreted in urine, 5% in faces
- Chloride: 60-150meq
  NS should not be used for maintenance fluid in pt. risk of hyperchloremic metabolic acidosis
- Bicarb: 1 meq/kg/day

Maintenance Therapy

- 0.45%NaCl or 5DN/2 (+ 20 mEq KCL) volume 2 L/day would be appropriate choices.
- Addition of D5 can be added to prevent muscle catabolism
- Avoid dextrose in pt. with uncontrolled DM or hypokalemia
- Adjust maintenance fluids based on serum Na concentration (ex. Change from N/2 to NSS or 5DNSS in hyponatremia pt.)

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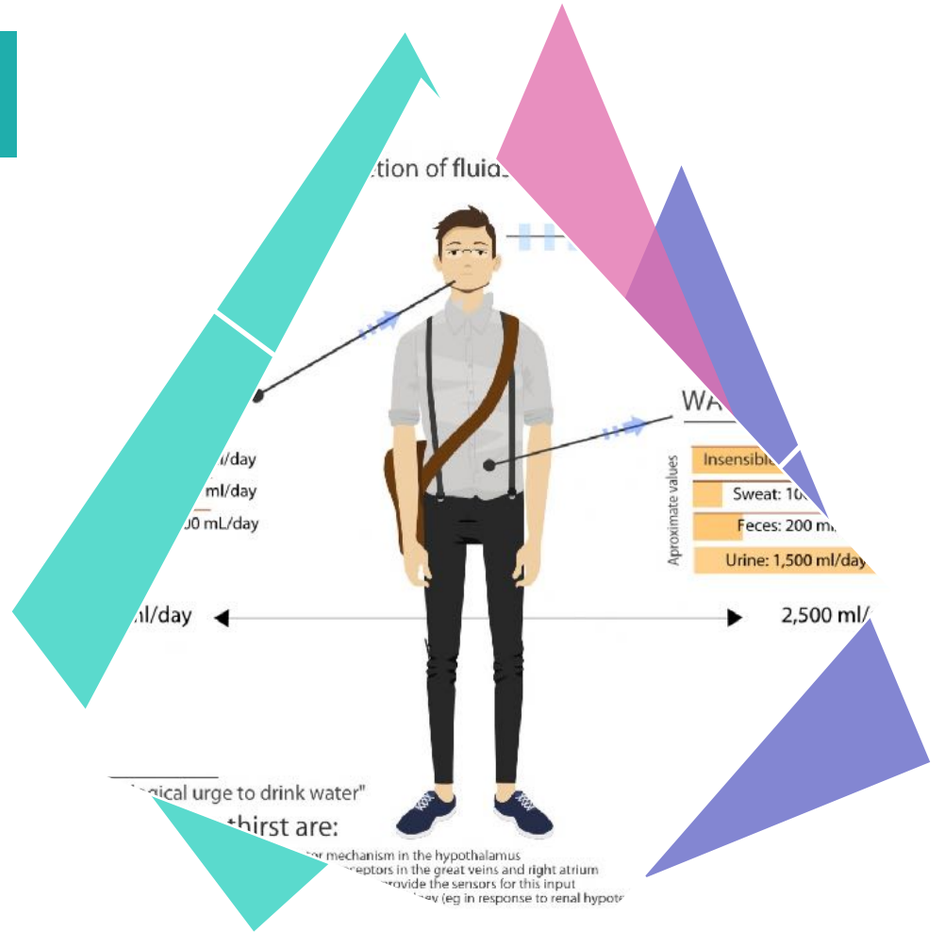
Maintenance Therapy

Maintenance

- pt. is not expected to eat or drink normally
- water and electrolytes under normal physiological



Ongoing loss

water and electrolytes under physiological conditions eg.

- gastric content =NSS/2,
- ECF, third space loss = balanced salt solution

Specific condition : ESRD or edematous states (ex. cirrhosis, heart failure) require less maintenance due to decreased output and/or altered fluid distribution

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5%DN/2
iv drip 80 ml/hr

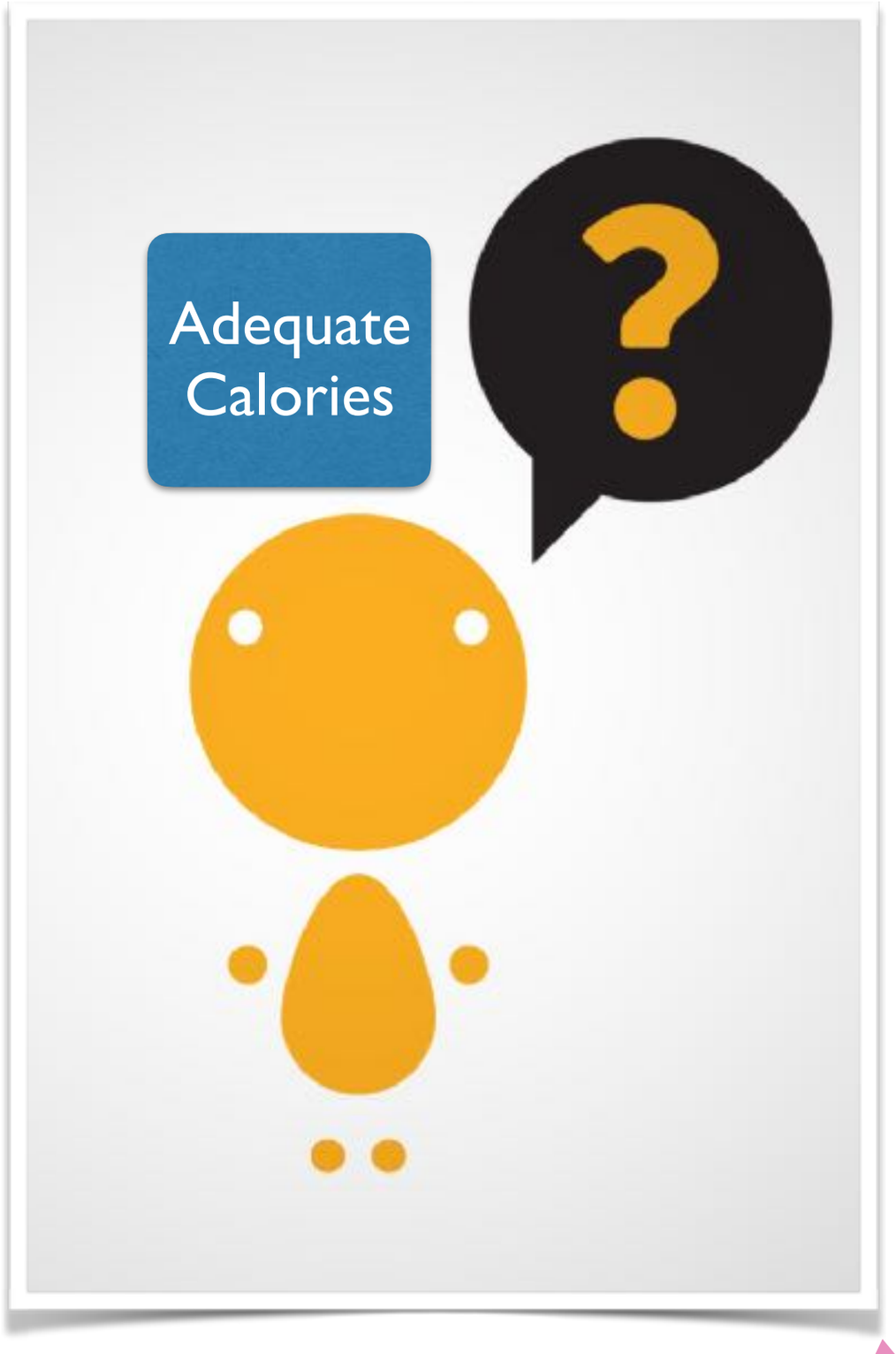
Dextrose 100 gm/d

Na 154 mEq/d

Cl 154 mEq/d

340 KCal/d

Volume 2 Litre /d



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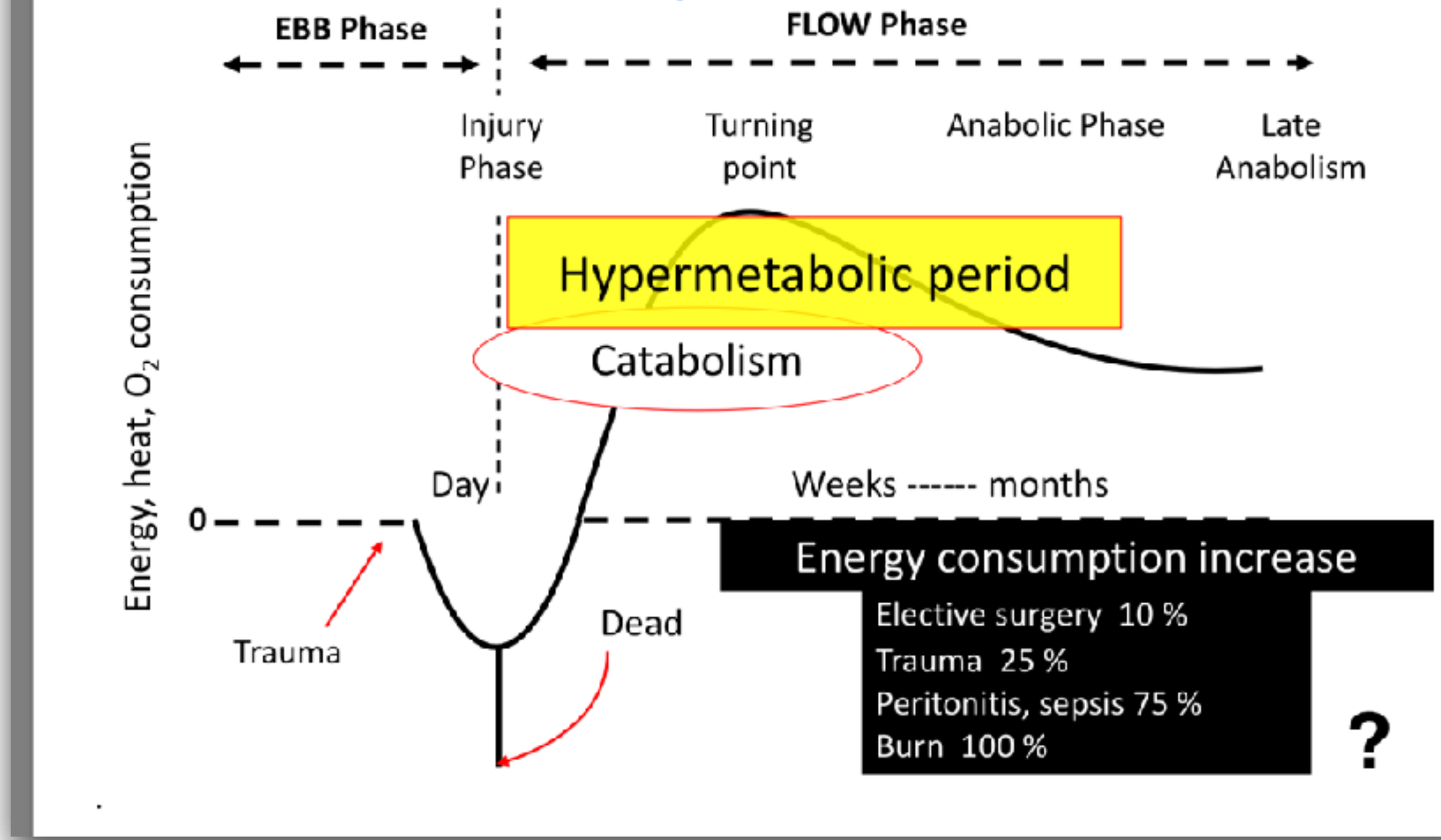
Phases of the response to injury: REE (Resting Energy Expenditure) is increased after the injury phase



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Zusman et al. Critical Care (2016) 20:367
DOI 10.1186/s13054-016-1538-4

Critical Care

RESEARCH Open Access

Resting energy expenditure, calorie and protein consumption in critically ill patients: a retrospective cohort study

Oren Zusman[1*], Miriam Theilla[2,3], Jonathan Cohen[2,4], Ilya Kagan[2], Itai Bendavid[2] and Pierre Singer[2,4]

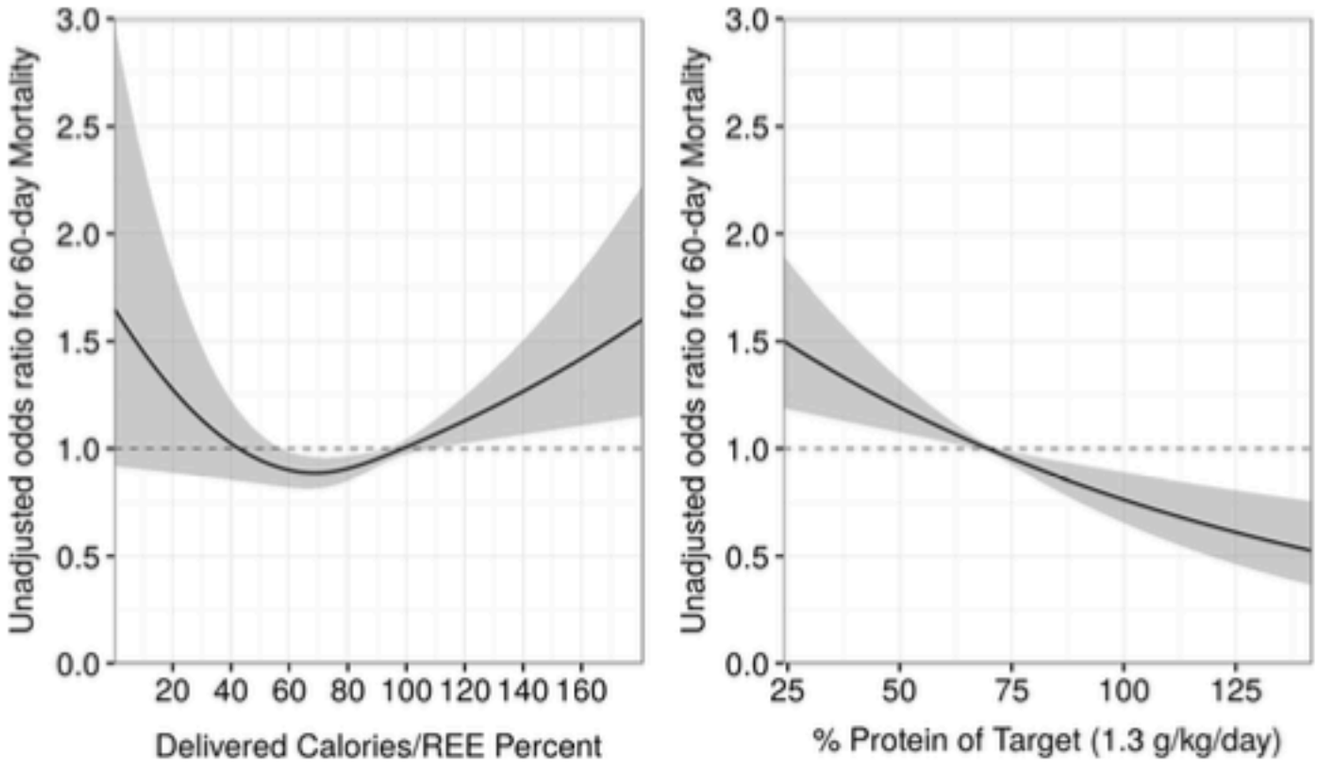
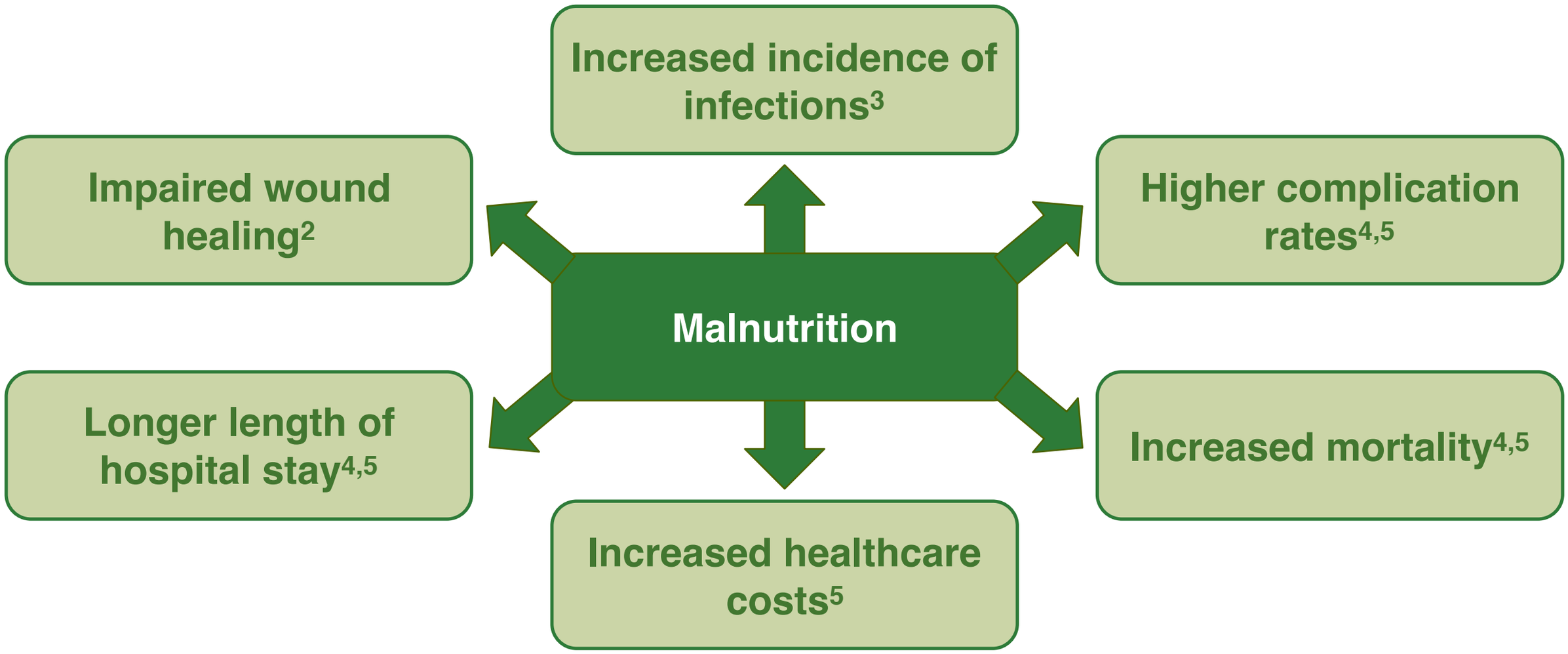


Fig. 2 Association of administered calories/resting energy expenditure (Adcal/REE) percent with 60-day mortality (*left*), and protein intake by daily requirement (1.3 g/kg/d) with 60-day mortality (*right*) by odds ratio. *REE* resting energy expenditure

Approximately 40% of hospital patients are malnourished[1]



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1. Norman K, et al. Clin Nutr 2008;27:5–15.
2. Haydock DA, Hill GL. J Parenter Enteral Nutr 1986;10:550–4.
3. Schneider SM, et al. Br J Nutr 2004;92:105–11.

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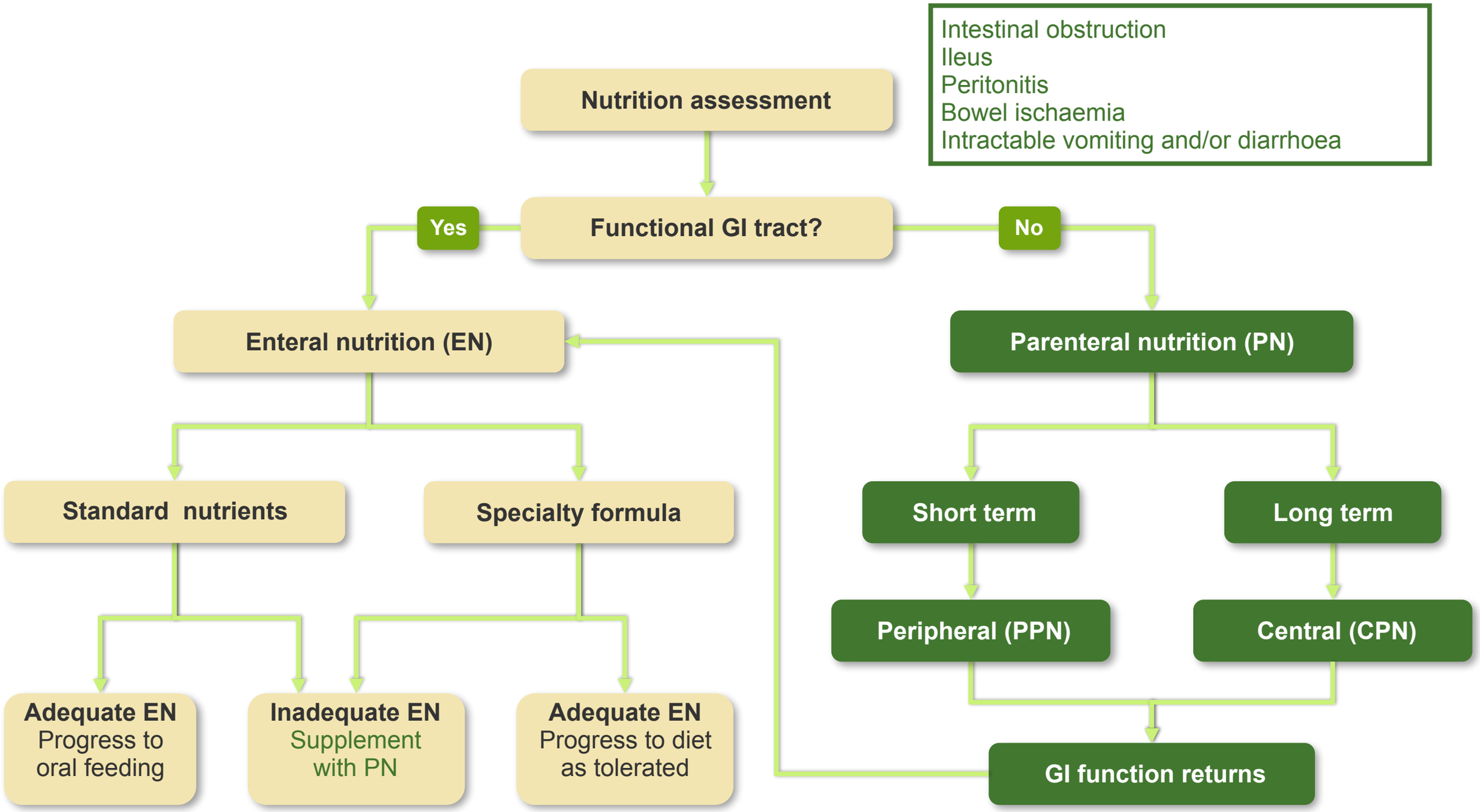
When is parenteral nutrition used?



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Adapted and abbreviated from Ukleja A, et al. Nutr Clin Pract 2010;25:403–14.

Guidelines for PN in critical care

	SCCM/ASPEN[1]		ESPEN[2]
Parenteral nutrition			
Patients	Previously healthy prior to critical illness with **no evidence of protein calorie malnutrition.**	**Evidence of protein-calorie malnutrition** on admission.	All patients who are not expected to be on normal nutrition within 3 days if EN is contraindicated or if they cannot tolerate EN.
Initiation of PN	Use of PN should be reserved and initiated only **after the first 7 days** of hospitalization (when EN is not available). ***Grade E***	Initiate PN as soon as possible following admission and adequate resuscitation (when EN is not available). ***Grade C***	**Within 24 to 48 hours.** ***Grade C***
Parenteral nutrition + Enteral nutrition			
Indication	If unable to meet energy requirements (100% of target goal calories). ***Grade E***		If unable to meet energy requirements (100% of target goal calories) with enteral. ***Grade C***
Initiation of PN	**After 7–10 days by the enteral route alone**, consider adding PN. ***Grade E***		After **2 days** of enteral feeding. ***Grade C***
Energy goal	Energy requirements may be calculated either through simplified formulas (25–30 kcal/kg/day), published predictive equations or use of indirect calorimetry. ***Grade E***		Equal to measured energy expenditure in order to decrease negative energy balance or 25 kcal/kg/day increasing to target over the next 2–3 days. ***Grade C***
Protein goal	1.2–2.0 g/kg/day in patients with BMI <30. ***Grade E***		~1.3–1.5 g/kg ideal body weight/day. ***Grade B***

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1. McClave et al, JPEN 2009;33:277–316.

2. Singer P, et al. Clin Nutr 2009;28:387–400.

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Clinical Nutrition 36 (2017) 623–650

Contents lists available at ScienceDirect

Clinical Nutrition

journal homepage: http://www.elsevier.com/locate/clnu

ESPEN guideline: Clinical nutrition in surgery

Arved Weimann [a, *], Marco Braga [b], Franco Carli [c], Takashi Higashiguchi [d], Martin Hübner [e], Stanislaw Klek [f], Alessandro Laviano [g], Olle Ljungqvist [h], Dileep N. Lobo [i], Robert Martindale [j], Dan L. Waitzberg [k], Stephan C. Bischoff [l], Pierre Singer [m]

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[f] General and Oncology Surgery Unit, Stanley Dudrick's Memorial Hospital, 15 Tyniecka Street, 32-050 Skawina, Krakau, Poland
[g] Dipartimento di Medicina Clinica, Universita "La Sapienza" Roma, UOD Coordinamento Attività Nutrizione Clinica, Viale dell'Università, 00185 Roma, Italy
[h] Department of Surgery, Faculty of Medicine and Health, Örebro University, Örebro, Sweden
[i] Gastrointestinal Surgery, National Institute for Health Research Nottingham Digestive Diseases Biomedical Research Unit, Nottingham University Hospitals and University of Nottingham, Queen's Medical Centre, Nottingham NG7 2UH, UK
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[k] Department of Gastroenterology, School of Medicine, LIM-35, University of Sao Paulo, Ganep — Human Nutrition, Sao Paulo, Brazil
[l] Institut für Ernährungsmedizin (180), Universität Hohenheim, 70593 Stuttgart, Germany
[m] Institute for Nutrition Research, Rabin Medical Center, Beilinson Hospital, Petah Tikva 49100, Israel

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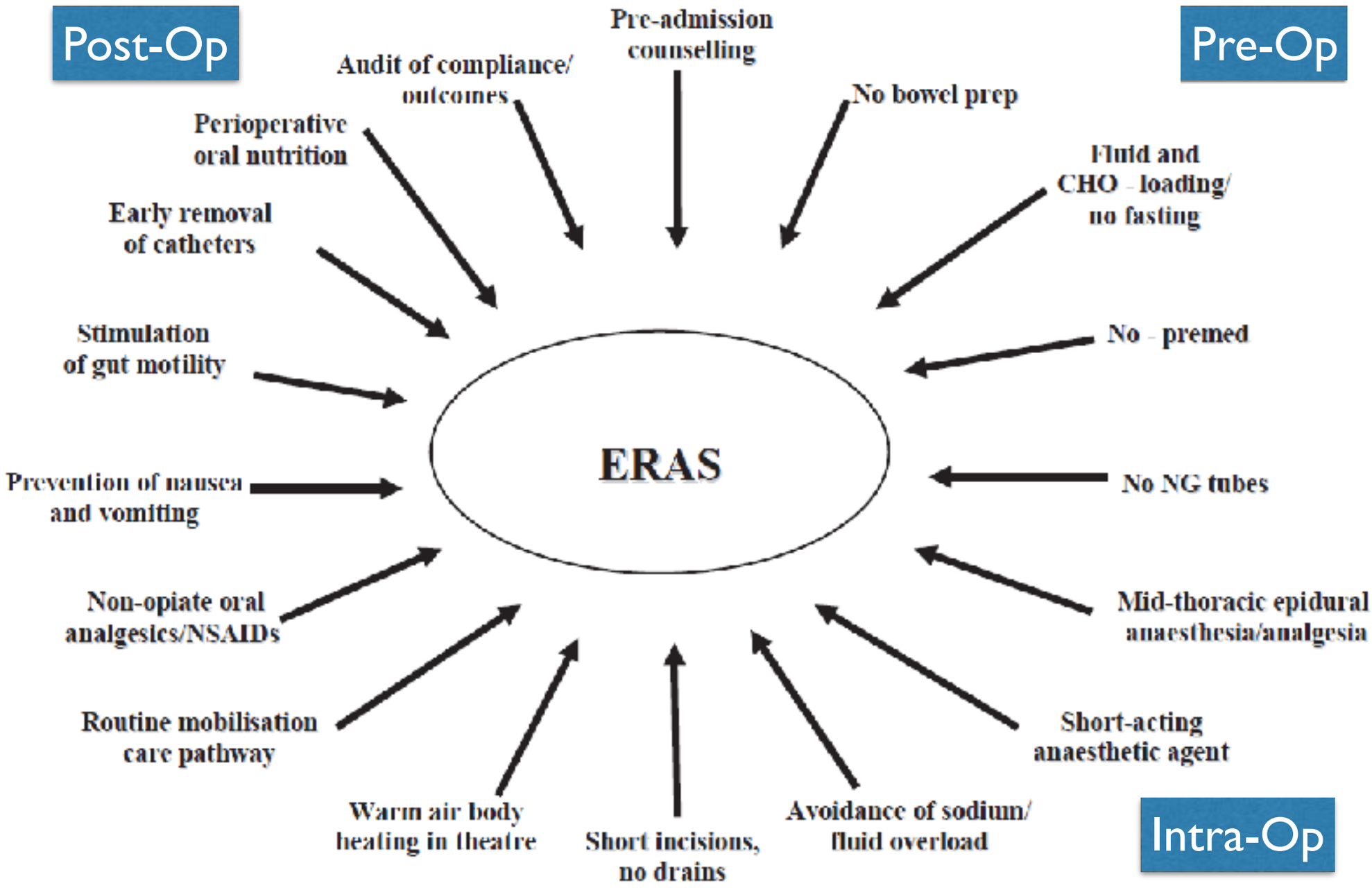
Main elements of the enhanced recovery after surgery (ERAS) clinical care protocol



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Fluid Resuscitation

- **Purpose:** Correct existing abnormalities in volume status or serum electrolytes
- Objective parameters used to assess volume deficit:
  - Blood pressure, heart rate
  - Jugular venous pressure,CVP
  - Capillary refill
  - Urine output
  - Pre and post deficit body weight
  - *Goal- directed hemodynamic management(CI >4.5 L/min/m2 ,DO2>600 ml/min/m2, SvO2>70 mmHg)

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Rate & Volume

- Mild to moderate hypovolemia?
  - Estimate fluid losses:
  - Average output 2.4L/day for 70kg patient
  - estimate additional losses e.g. GI (diarrhea, vomiting), high fever(add 100ml/day for each degree of BT > 37C)
  - Select fluid based on type of fluid that has been lost and any co-existing electrolyte disorders
- Severe volume depletion or hypovolemic shock?
  - Rapid infusion of 1-2L isotonic saline (NSS), then re-assess parameters
  - use Lactated/Acetate Ringers if concern for hyperchloremic metabolic acidosis

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Effect of chloride rich solution

Metabolic	• Hyperchloremic acidosis • ↑Need for buffers to correct acidosis
Body water	• Possible damage to the endothelial glycocalyx • ↑Interstitial fluid volume leading to edema
Renal	• Renal edema and capsular stretch leading to intrarenal tissue hypertension • Renal vasoconstriction, ↓renal blood flow and renal tissue perfusion • ↓Glomerular filtration rate, urine volume, and sodium excretion
Gastrointestinal	• Gastrointestinal edema, intestinal stretch • Ileus, impaired anastomotic healing
Hematological	• ↑Intraoperative blood loss • ↑Need for blood product transfusion
Clinical outcomes	• ↑Postoperative complications • ↑Mortality • ↑Incidence of acute kidney injury and need for renal replacement therapy

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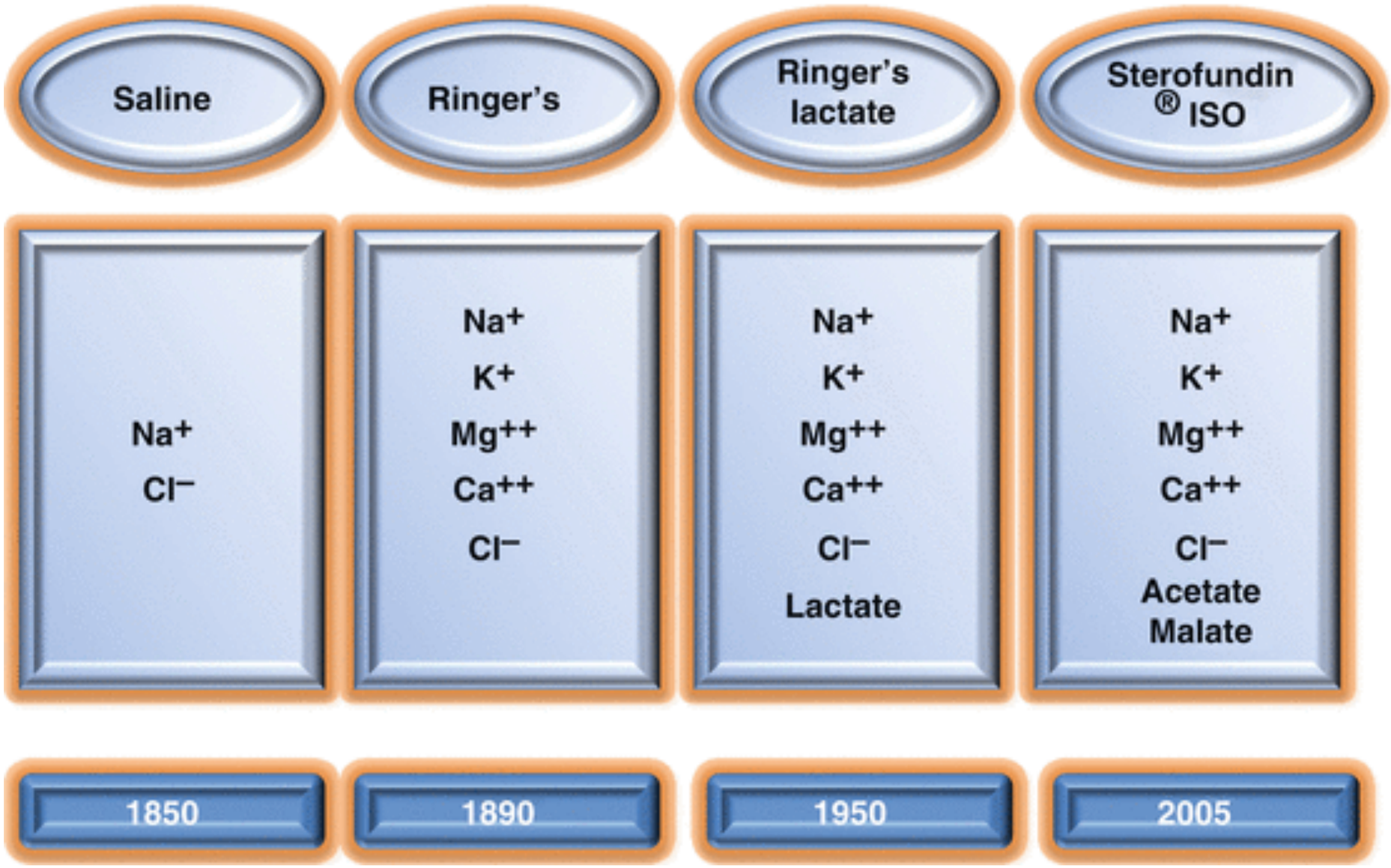
Type of resuscitate fluid

- **Crystalloid**
  - 0.9NSS
  - Ringer lactate solution
  - Ringer acetate solution
  - Plasmalyte
  - Sterofundin
- **Colloid**
  - Gelatin eg. Gelofusine ,Hemaccel e
  - Starch eg. Haes-steril ,Voluven
  - Polysaccharide: Dextran
  - Human albumin

Development of IV fluid



0.9%NaCl >>>>>> Balanced cystalloid

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SID (strong ion difference)

- strong ions **do not hydrolyze** in aqueous solution
- Na^+, K^+, Cl^-
- SID = $[Na^+] + [K^+] - [Cl^-]$ = 142 + 4 – 103 = 43 mmol/l
- physiological range of SID = 39 – 45 mmol/l

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Crystalloid

- solute + solvent +/- dextrose
- Effective plasma osmolality = 2 x [**Na+**] + glucose + urea
- Hypotonic/ Isotonic/ Hypertonic
- Isotonic กระจายในECF compartment (20-30min)และคงอยู่ใน intravascular 1/3-1/4 ส่วน นาน1-2ชม.
- Nondextrose Isotonic (NSS,LRS,ALS) ใช้ 3-4 เท่าของปริมาณเลือดที่สูญเสีย
- ราคาถูก ,allergic reaction น้อย
- Dilution coagulopathy, Interstitial/pulmonary edema

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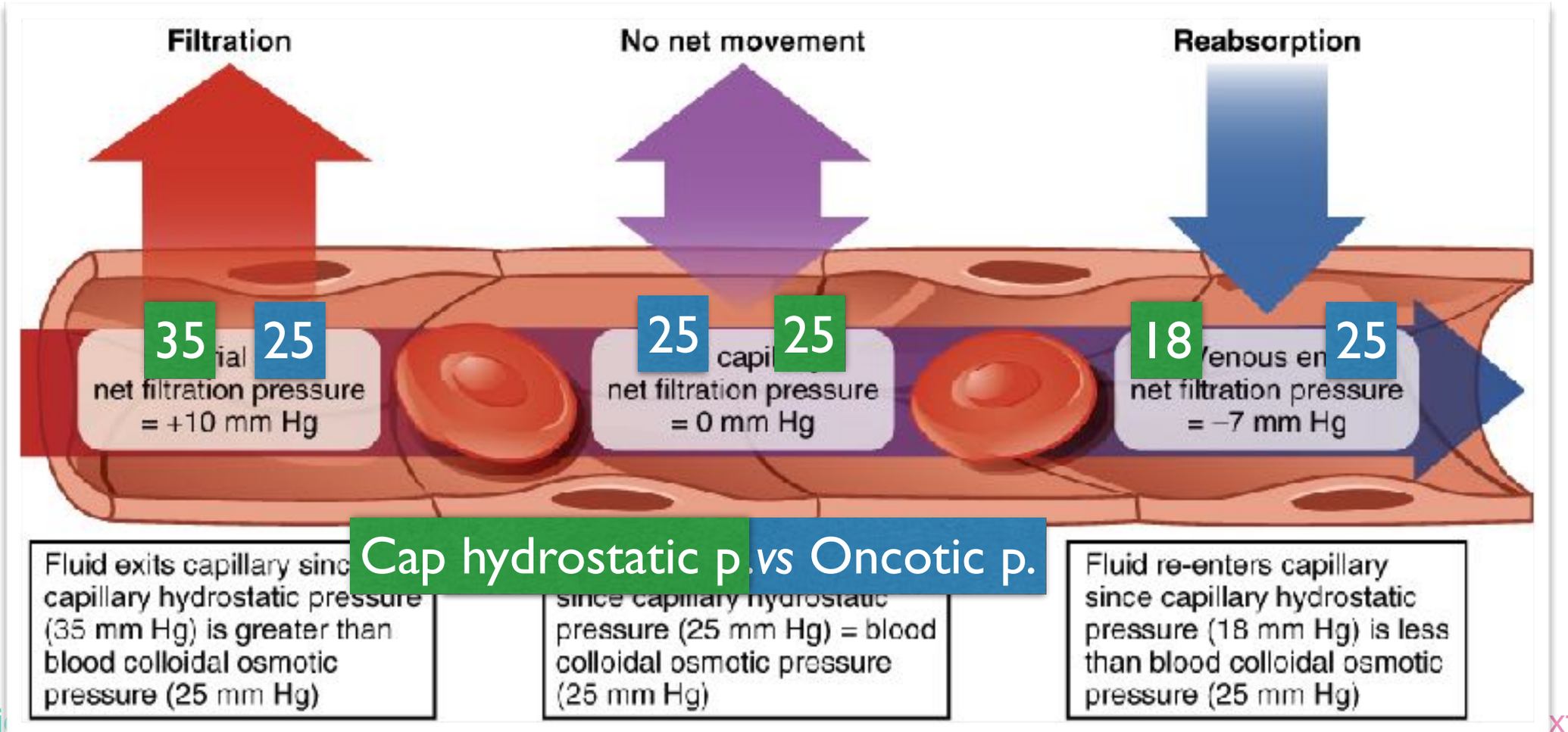
Colloid

- MW ใหญ่ , oncotic p.สูง
- ใช้ 1-1.2 เท่าของปริมาณเลือดที่สูญเสีย
- คงอยู่ใน intravascular นาน2-4ชม.(normal capillary permeability)



OpenStax, Anatomy & Physiology. 2016

Colloid

- MW ใหญ่ , oncotic p.สูง
- ใช้ 1-1.2 เท่าของปริมาณเลือดที่สูญเสีย
- คงอยู่ใน intravascular นาน2-4ชม.(normal capillary permeability)
- ราคาแพง : Human Albumin>Starch ~Gelatin >Dextran
- Allergic reaction: Dextran>Gelatin>Human Albumin>Starch
- Dilution coagulopathy, impair platelet aggregation esp.Starch

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Colloid

Starch

Gelatin

Human albumin

Dextran

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Endothelial glycocalyx

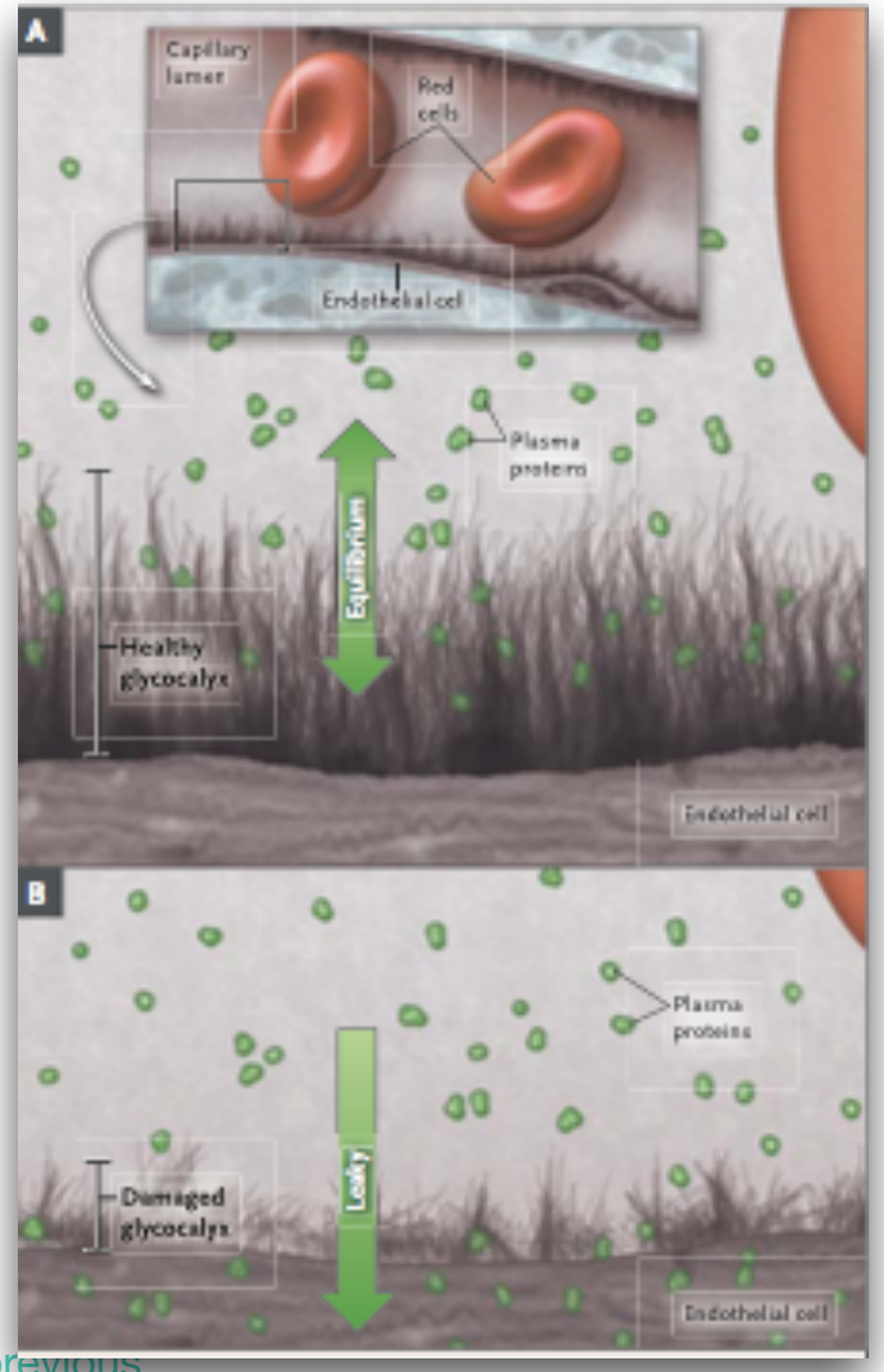

Figure 1. Role of the Endothelial Glycocalyx Layer in the Use of Resuscitation Fluids.

The structure and function of the endothelial glycocalyx layer, a web of membrane-bound glycoproteins and proteoglycans on endothelial cells, are key determinants of membrane permeability in various vascular organ systems. Panel A shows a healthy endothelial glycocalyx layer, and Panel B shows a damaged endothelial glycocalyx layer and resultant effect on permeability, including the development of interstitial edema in some patients, particularly those with inflammatory conditions (e.g., sepsis).

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Myburgh JA et.al NEJM 2013; 13:369

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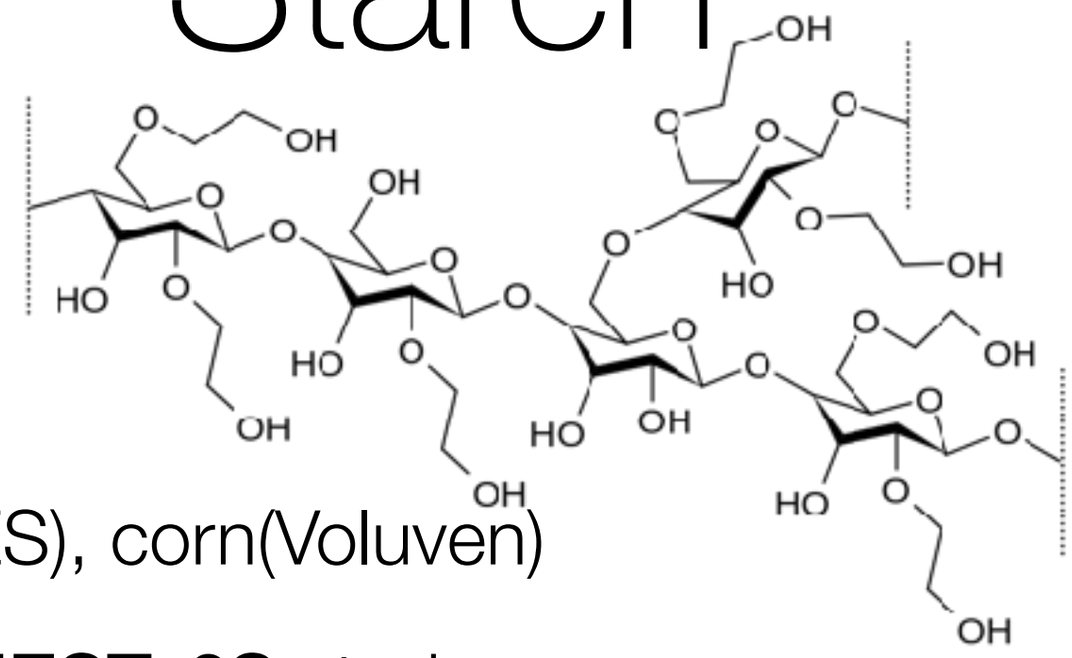
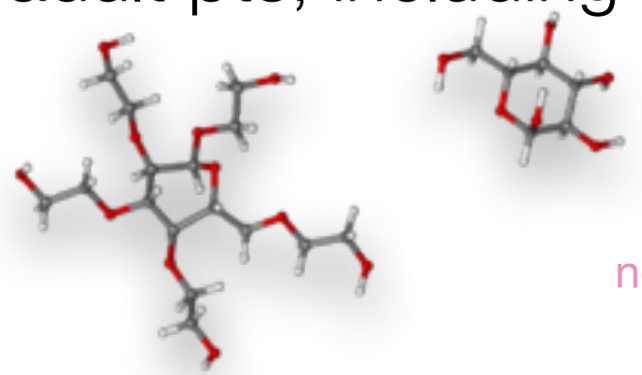
Starch



- Potato(HES), corn(Voluven)
- **VISEP,CHEST, 6S** study
- ‘The Surviving Sepsis Campaign’ ban Starch from treatment in sepsis pts.
- November 25, 2013, the **USFDA** ‘black box warning’ to the prescribing information

- Do not use HES solutions in critically ill adult pts, including sepsis.



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Starch

- Avoid use in patients with pre-existing renal dysfunction.
- Discontinue use of HES at the first sign of renal injury.
- Need for RRT has been reported up to 90 days after HES administration. Continue to monitor renal function for at least 90 days in all pts.
- Avoid use in pts undergoing open heart surgery in ass. with CPB due to excess bleeding.
- Discontinue use of HES at the first sign of coagulopathy.
- Do not use HES in pts with severe liver disease
- Monitor liver function in pts receiving HES products.

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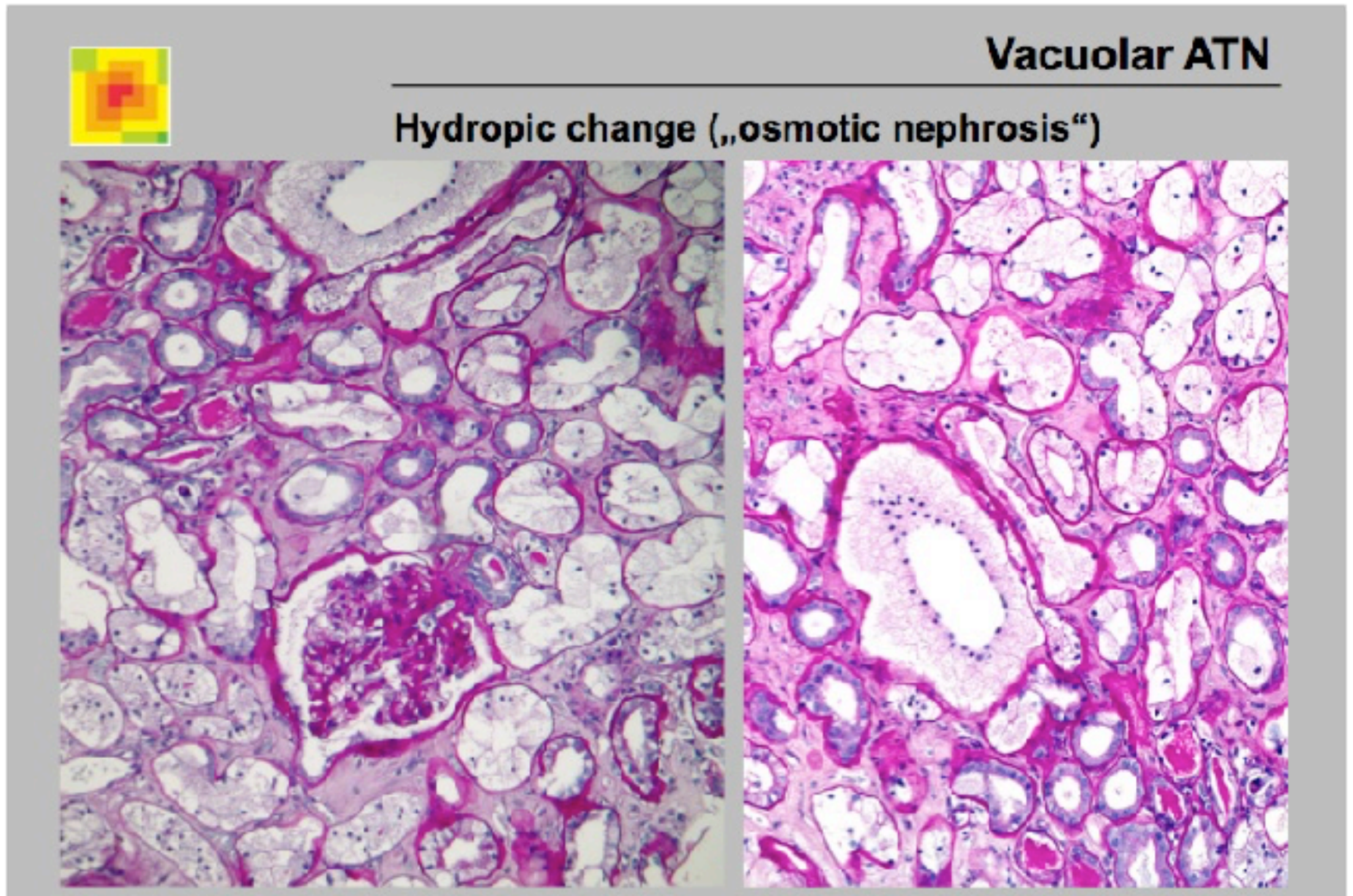
Starch


Vacuolar ATN
Hydropic change („osmotic nephrosis“)
Severe fine vacuolar degeneration of the tubules

Gelatin

- Semisynthetic colloid solutions.
- A recent observational study has raised concern about the risk of acute kidney injury
- No high-quality RCT to date.
- Current evidence of the lack of clinical benefit, potential nephrotoxicity, and increased cost
- The use of semisynthetic colloids for fluid resuscitation in critically ill patients is difficult to justify.

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Anaesth Intensive Care 2012; **40**: 17-32

Reviews

Benefits and risks of using gelatin solution as a plasma expander for perioperative and critically ill patients: a meta-analysis

M. M. SAW*, B. CHANDLER†, K. M. HO‡

Intensive Care Department, Royal Perth Hospital, Perth, Western Australia, Australia

P=0.04). These findings suggest that using gelatin solutions is associated with a lower risk of acute renal failure compared to older starches. Using gelatin as a plasma expander appears to have no significant advantages over crystalloids or isotonic albumin on mortality and may have a slightly higher risk of requiring allogeneic blood transfusion in perioperative and critically ill patients. An adequately powered randomised controlled trial with economic analysis is needed before gelatin solution can be recommended as a routine plasma expander for patients undergoing major surgery or who are critically ill.

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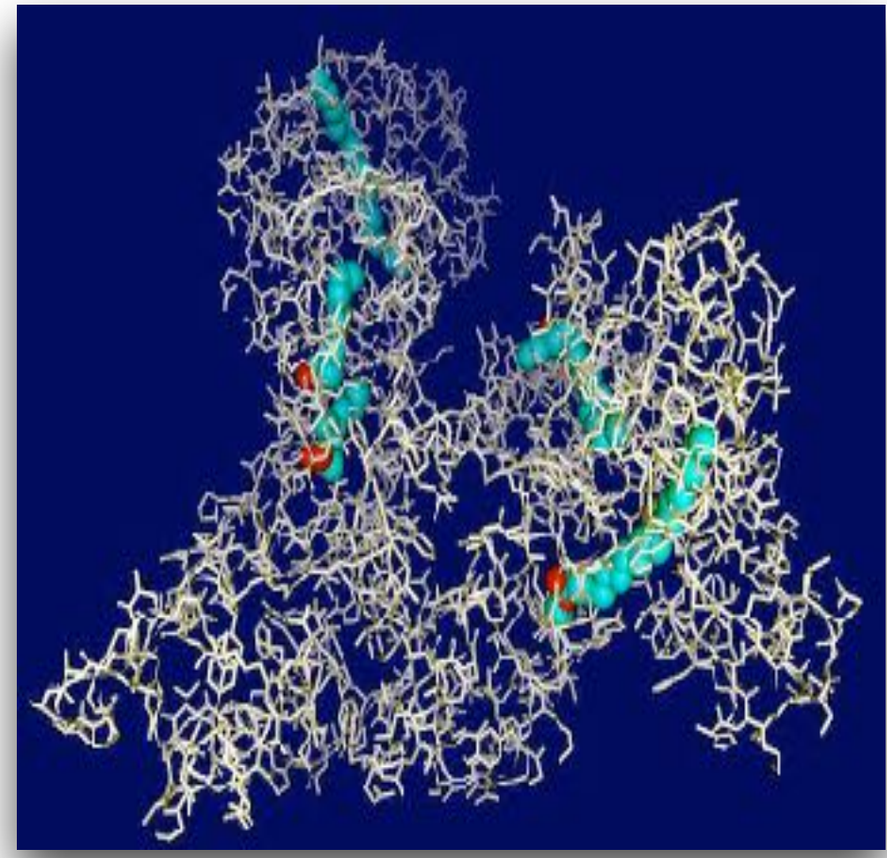
Human albumin



- Normal plasma is 3500-4500mg/dl
- Synthesized in the liver
- Serum half-life~ 20 days
- A major function of albumin is its role in osmotic regulation (75- 80 % of the osmotic effect of plasma)
- Negatively charged
- Degradation is poorly understood

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Human albumin

- ผลิตจาก human plasma ทำให้ปลอดเชื้อ
- 5%human alb $t^{1/2}$ ~16 hrs (shorter in sepsis) oncotic p ~ plasma คงอยู่ในvasc.~80%
- 20-25%human alb oncotic p> plasma เพิ่มปริมาณplasma ได้4-5 เท่าของปริมาตรที่ให้ t1/2 ~16-24 hrs (shorter in sepsis)
- The 20-25 % solution is typically given if the pt is hypervolemia

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Indications for albumin admin.

- Following large volume paracentesis
- Nephrotic syndrome resistant to potent diuretics
- Volume/Fluid replacement in plasmapheresis
- Serum albumin <2.5 g/dl with ineffective intravascular volume
- ARDS
- Extensive burns (>15%)

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Indications for albumin admin.

- Cardiopulmonary bypass pump(CPB) priming
- Fluid resuscitation in sepsis/septic shock
- Intraoperative fluid requirement > 5-6 L in adults
- Neonatal kernicterus Plasma exchange
- Premature infant undergoing major surgery

Human albumin

- Spontaneous Bacterial Peritonitis

(Salerno F, et al.Albumin infusion improves outcomes of patients with spontaneous bacterial peritonitis: a meta-analysis of randomized trials. Clin Gastroenterol Hepatol. 2013 Feb;11(2):123-30.e1. doi: 10.1016/j.cgh.2012.11.007. Epub 2012 Nov 22.)

- Hepatorenal syndrome

(Duvoux C, et al. Effects of noradrenalin and albumin in patients with type I hepatorenal syndrome: a pilot study. Hepatology. 2002 Aug;36(2):374-80.)

- Adjunct to large volume paracentesis (>5L) in treatment of diuretic-resistant ascites in cirrhosis.

(Bernardi M, et al. Albumin infusion in patients undergoing large-volume paracentesis: a meta-analysis of randomized trials. Hepatology. 2012 Apr;55(4):1172-81. doi: 10.1002/hep.24786.)

- Therapeutic plasma exchange and/or plasmapheresis.

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Not indicated

- Correction of measured hypoalbuminemia
- Nutritional deficiency, TPN
- Pre-eclampsia
- Simple volume expansion (surgery, burns)
- Wound healing

Contra-indication

- Hypersensitive to albumin
- pts at risk of developing circulatory overload (CHF, renal insuffciency, chronic anemia)

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Human albumin for resuscitation

- ใช้เมื่อไม่ตอบสนองต่อการให้crystalloid เนื่องจากoncotic p.ต่ำ
- Rapid plasma volume expansion, colloid solution remains in vascular space.
- Lesser risk of pulmonary edema due to dilutional hypoalbuminuria
- ไม่รบกวนการแข็งตัวของเลือด
- ใช้ทดแทนการสูญเสียน้ำร่วมกับ protein eg. burn ,ascites tapping

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Human albumin

- **CRISTAL randomized trial :** ‘Effects of fluid resuscitation with colloids vs crystalloids on mortality in critically ill patients presenting with hypovolemic shock’(Annane D, et al.JAMA. 2013 Nov 6;310(17):1809-17.)
- No difference in 28-day mortality between colloids vs crystalloids. However, Colloids had more days free of MV (13.5 vs 14.6 days) and vasopressor therapy (15.2 vs 16.2 days), as well as a lower 90-day mortality(31vs 34 %).
- Confidence of benefit was limited by open-label design, lengthy study period, and heterogeneity of fluids that were compared between the groups.

- ‘Albumin replacement in patients with severe sepsis or septic shock’ (Caironi P, et al.N Engl J Med. 2014 Apr 10;370(15):1412-21.)
- In pts with severe sepsis, albumin replacement in addition to crystalloids, as compared with crystalloids alone, did not improve the rate of survival at 28 and 90 days.

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Fluid Therapy of Severe Sepsis

- ให้สารน้ำ Crystalloids เป็นชนิดแรกสำหรับ resuscitation ผู้ป่วย Severe sepsis/Septic shock (1B)
- Initial fluid challenge should be ≥1L of crystalloid, and a minimum of 30 mL/kg of crystalloid in the first 4-6 hours.
- ไม่แนะนำให้ใช้ Hydroxyethyl starches (HES,Voluven) (B)
- ถ้าต้องให้ให้ Crystalloids เป็นปริมาณมากสามารถให้ Human albumin ร่วมด้วยได้(2C)

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Intensive Care Med
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CONFERENCE REPORTS AND EXPERT PANEL

Surviving Sepsis Campaign: International Guidelines for Management of Sepsis and Septic Shock: 2016

- We suggest using **albumin** in addition to crystalloids for initial resuscitation and subsequent intravascular volume replacement in pts with sepsis and septic shock when pts require substantial amounts of crystalloids (weak recommendation, low quality of evidence).

- We recommend **against** using hydroxyethyl starches (HESs) for intravascular volume replacement in pts with sepsis or septic shock (strong recommendation, high quality of evidence).

- We suggest using crystalloids over gelatins when resuscitating pts with sepsis or septic shock (weak recommendation, low quality of evidence).

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Adverse effect of fluid therapy

Fluid overload/positive fluid balance ass. with

Increase :LOS, mortality

AKI, MODS

Potential harms: Time, Dose ,Type of fluid in specific clinical context

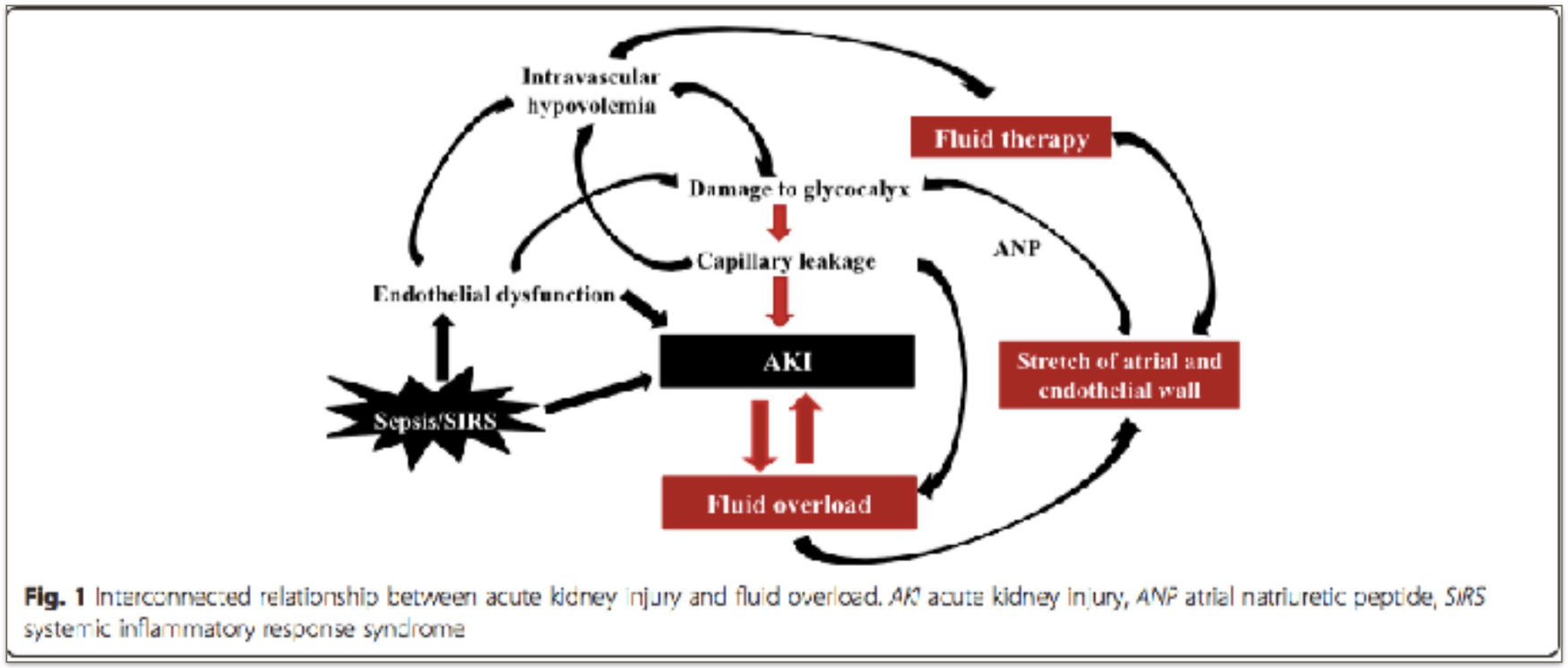

Fig. 1 Interconnected relationship between acute kidney injury and fluid overload. *AKI* acute kidney injury, *ANP* atrial natriuretic peptide, *SIRS* systemic inflammatory response syndrome

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Ostermann et al. Critical Care 2015; 19:443

REVIEW ARTICLE

CRITICAL CARE MEDICINE

Simon R. Finfer, M.D., and Jean-Louis Vincent, M.D., Ph.D., *Editors*

Resuscitation Fluids

John A. Myburgh, M.B., B.Ch., Ph.D., and Michael G. Mythen, M.D., M.B., B.S.

Table 2. Recommendations for Fluid Resuscitation in Acutely Ill Patients.

Fluids should be administered with the same caution that is used with any intravenous drug.

Consider the type, dose

Specific considerations

Bleeding patients requir … as indicated.

Isotonic, balanced salt s … patients.

Consider saline in patie

Consider albumin durin

Saline or isotonic crystal

Albumin is not indicated

Hydroxyethyl starch is n

- RBC for bleeding resuscitation
- Isotionic Balanced salt solution
- NSS in hypovolemia & alkalosis,TBI
- Albumin early in severe sepsis

- Albumin is not indicated in TBI
- HESs not indicated in SEPSIS,AKI

- Semisynthetic colloidis safe?
- Hypertonic saline is safe?
- Appropriated type& dose in burn has not been determine

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Myburgh JA et.al NEJM 2013; 13:369

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Doctor must know

- Treat IV fluids as a prescription as medication, with consideration of renal function and clinical picture
- Determine if pt needs maintenance or resuscitation
- Choose rate of fluid administration based on weight and minimal daily requirements
- Choose fluid type based on co-existing electrolyte disturbances
- Don’t forget additional IV medications
- Avoid fluids in pts with ECF volume excess
- Assess DAILY whether the pt continues to require IVF

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Fluid is still the best medicine

- Fluid therapy should be prescribe as drug: Indication/contra-indication/ Type/Dose/ Rate
- Tailored to the specific clinical context, EBM
- Time, phase-dependent consideration
- Optimum fluid & monitoring for **toxicity**

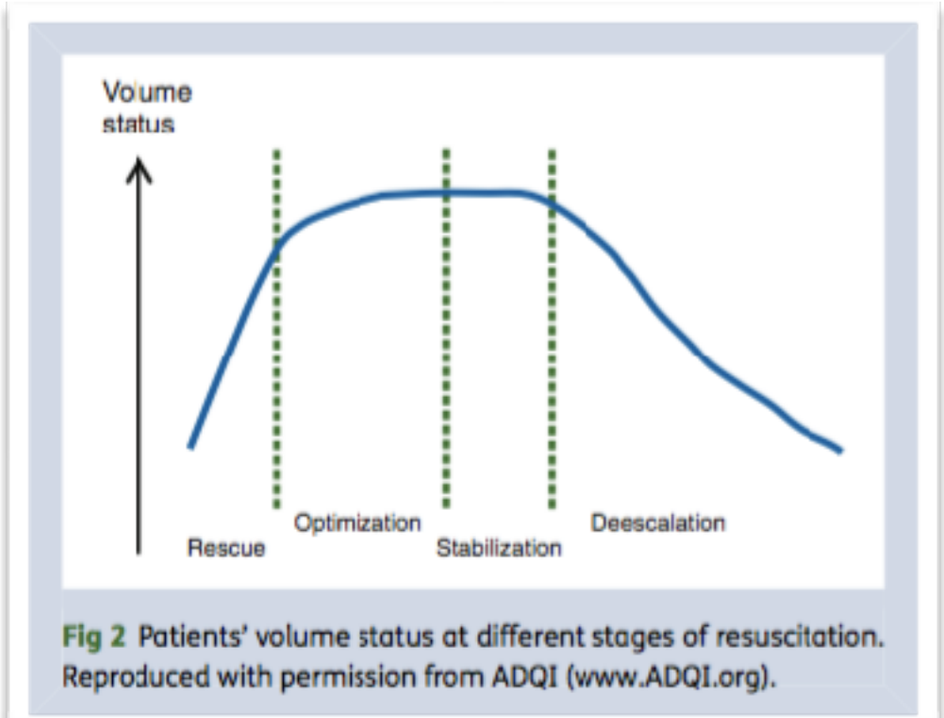
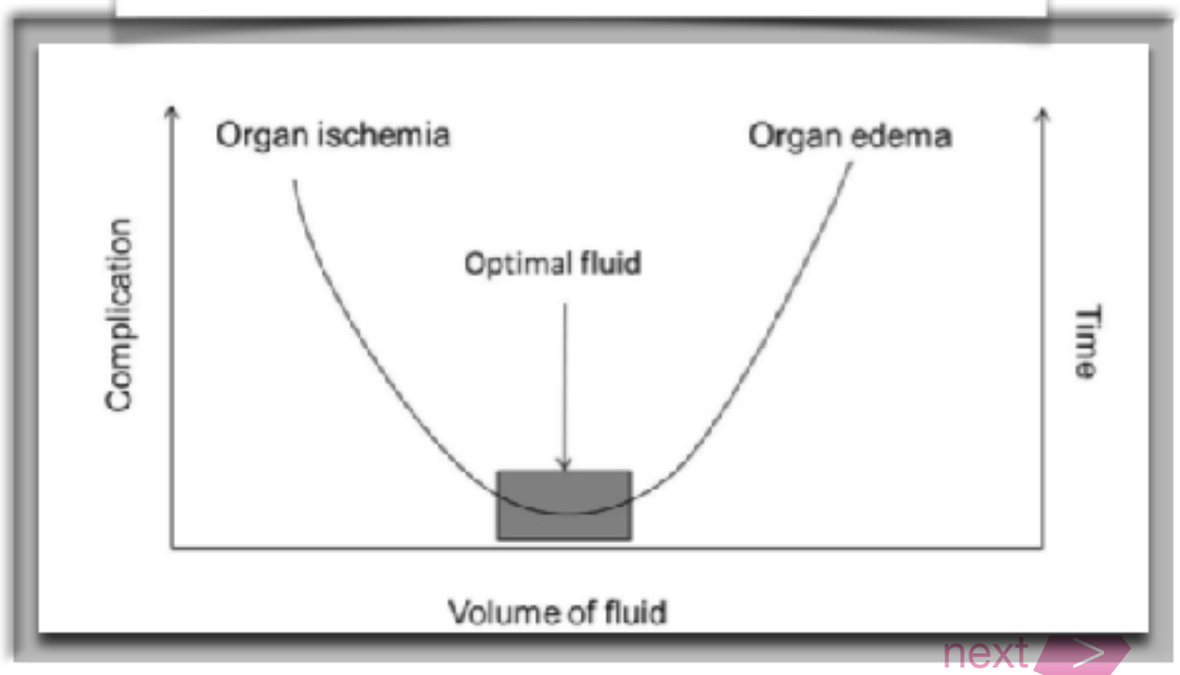


Fig 2 Patients' volume status at different stages of resuscitation. Reproduced with permission from ADQI (www.ADQI.org).



Murugan R, Kellum JA Crit Care Med 2012; 40: 1970–2

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