


IV FLUIDS: “A *CRYSTAL CLEAR SOLUTION*”



Dr Wayne Riback
(MBBCh)(D.Anaes.)
Adcock Ingram Critical Care


INTRODUCTION

- Fluid therapy - frequently poorly planned and implemented.
- Lack of knowledge of fluid composition.
- No rational principles for the fluid chosen.
- Fluid therapy has always been a misunderstood and difficult topic.
- Fluid prescriptions as serious as drug prescriptions.

- 
- Planning rationale :
 1. Choose fluid for a purpose
 2. Know its composition
 3. Be aware of risks and benefits
 - Aim to clarify and dispel some of the controversies about fluids and fluid therapy.


FLUID COMPARTMENTS


- Average male 60% water, female 50%.
- Distributed between two major compartments:
 1. Intracellular fluid compartment
 2. Extracellular fluid compartment
 - interstitial
 - intravascular
 - transcellular (CSF,ah)₄

- 
- All divided by cell membranes.
 - The volume of fluid (water) within a compartment is determined by its solute composition and concentrations.
 - Osmotic forces of “trapped” solutes govern water distribution between compartments and volume.

INTRACELLULAR FLUID


- Outer membrane important regulator of intracellular volume and composition.
- Driven by ATP membrane pump.
- Exchanges sodium for potassium.
- Membranes are less permeable to sodium.
- As a result **k⁺ high concentration I/c**
Na⁺ high concentration e/c

- 
- K^+ most important determinant of I/c osmotic pressure and Na^+ of e/c.
 - High intracellular concentration of proteins due to impermeable cell membrane.
 - Exchange of $3Na$ for $2K$ prevents hyperosmolality intracellularly.
 - But if one gets interference of Na-K-ATP pump e.g. by ischaemia or hypoxia.

- 
- If this does occur one will get progressive cell swelling
 - Eventual cell death.

EXTRACELLULAR FLUID

- Divided into: - A. interstitial
- B. intravascular
- Function: provide cells with nutrients and remove waste products.
- Maintenance of normal extracellular volume is critical esp. intravascular.

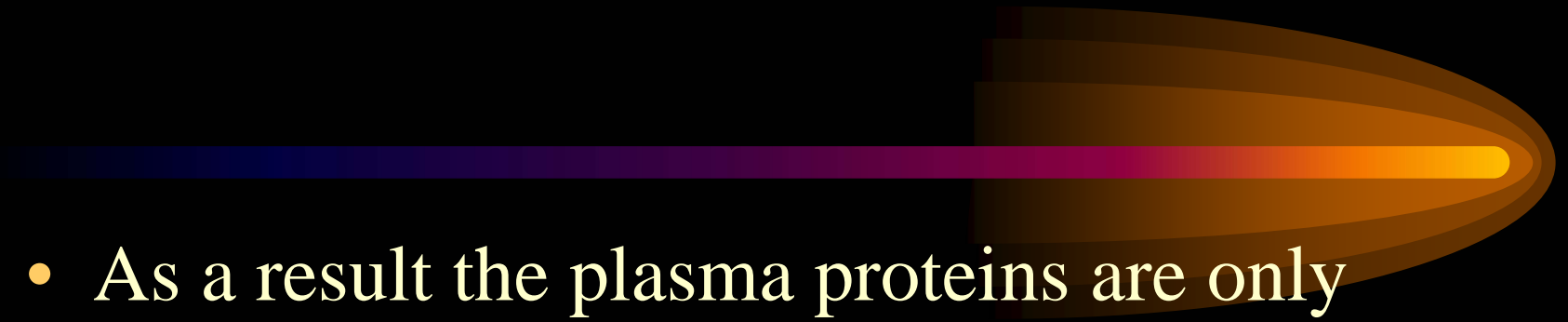
- 
- Na^+ is most important cation
 - Responsible for e/c oncotic pressure and volume.
 - Changes in total body Na result in changes in e/c fluid volume.
 - Na intake
 - renal Na excretion
 - extrarenal Na losses

A. INTERSTITIAL FLUID

- Very little as free fluid.
- Gel by chemical association with e/c proteoglycans.
- Normal interstitial pressure is - 5mmHg.
- If interstitial fluid volume increases, the pressure will also and become more +.
- Free fluid in gel = “oedema” clinically
- Very little protein -- lymphatic system

B. INTRAVASCULAR FLUID

- **PLASMA**
- Restricted to intravascular space by vascular endothelium.
- Almost identical composition to interstitial fluid (free passage between).
- But tight intercellular junctions, therefore plasma proteins cannot travel out.

- 
- As a result the plasma proteins are only osmotically active solutes in fluid exchange between plasma and interstitium. (albumin)
 - Interstitial acts as an overflow for excess fluid from the intravascular space --- tissue oedema.

COMPOSITION OF FLUID COMPARTMENTS

Meq/L	INTRACELL	INTRAVAS	INTERSTIT.
Na	10	145	142
K	140	4	4
Ca	1	3	3
Mg	50	2	2
Cl	4	105	110
Bicarb	10	24	28
Phosphate	75	2	2
Protein	16	7	2

DEFINITIONS




- **Osmotic pressure**
 - “pressure to be applied to side with more solute to prevent net movement of water down its concentration gradient.”
 - normal depends on nondiffuseable solute particles.



- **Osmolarity**

- “concentration of osmotically active particles.”
- expressed as osmoles.
- osmolar concentration is solely dependent on number of particles in solution.
- osmolarity = **milliosmoles/litre of solvent**

- 
- sum of ionized and non-ionized particles in solution.
 - Normal plasma osmolarity is 285-290mOsm/litre.



- **Osmolality**

- number of milliosmoles/kg of solvent.
- measured by depression of freezing point.
- plasma freezing point is -0.54°C .
- osmolality is 290 mOsmol/kg.



- **Oncotic pressure**

- difference between osmotic pressure of plasma and ECF.

- small effect.

- Starling's forces.

- determine the movement of fluid across capillary membranes.

- 
- Starling equation:

$$J_v = k((P_c - P_t) - \sigma(\pi_c - \pi_t))$$

J_v = fluid flux across membrane

k = diffusion constant

P_c = capillary hydrostatic pressure

P_t = tissue hydrostatic pressure



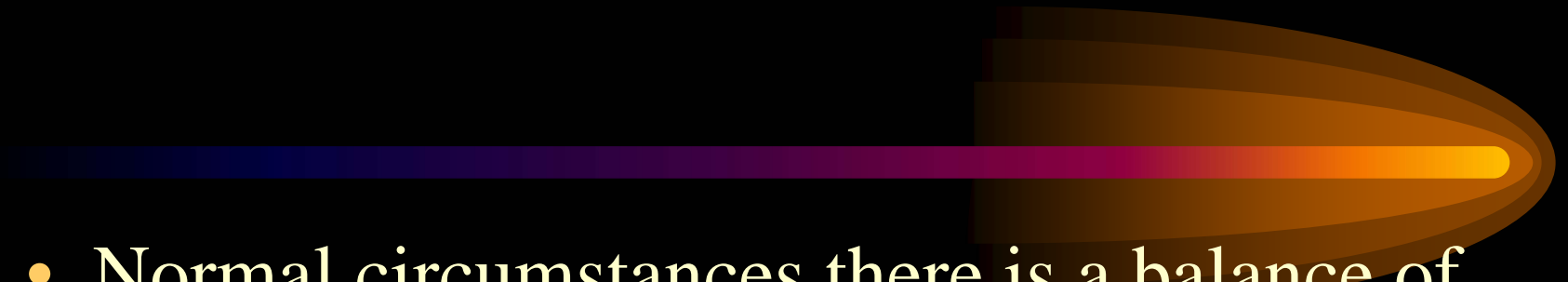
@ = reflectance coefficient

#c = oncotic pressure of plasma

#t = oncotic pressure of tissue

- @ varies in organs- 1 brain, kidney
0.3 liver

if endothelium is damaged e.g. disease can 0

- 
- Normal circumstances there is a balance of forces so that fluid leaves at the arteriolar end of the capillary and re-enters at the venular end.

FLUID MANAGEMENT



- Which fluid to choose?
- Crystalloid vs. colloid vs. Blood
- Important to consider the advantages and disadvantages of both.

CRYSTALLOIDS

- Extracellular space expanders.
- Net effect is 1/3 to 1/4 of total fluid infused.
- Limited volume expansion.
- Maintain urine output and renal function.
- Reduce plasma oncotic pressure by diluting plasma proteins.
- Variable electrolyte content.
- Cheap

COLLOIDS



- Intravascular space expanders.
- Volume for volume expansion.
- Maintain oncotic pressure.
- Coagulation problems.
- Variable electrolyte content and $t_{1/2}$.
- Adverse reactions.
- Expensive.

BLOOD AND BLOOD PRODUCTS



- Is a “toxic” solution
 - disease and allergy risk
 - debris
 - acidotic
 - hyperkalaemic
 - citrate toxicity
- Not to be used as a plasma expander!

USES OF INTRAVENOUS FLUIDS



1. Resuscitation
2. Rehydration/Replacement
3. Maintenance
4. Special purpose - TPN

RESUSCITATION

- Prompt recognition and treatment of traumatic injury.
- Decisions and therapeutic interventions must be rapid and correct.
- **Shock** = “potentially fatal disease caused by cellular injury and inadequate tissue perfusion”.

RESUSCITATION

- Experience will dictate the urgency and volume to prevent irreversible changes.
- Cerebration - confusion, serious, severe.
- Monitor - temp, resp rate, arterial BP, pulse.
- Urine output - indication of renal function.
- Venous pressure - esp CVP.
- Haematology - Hb, Hct, urea, lactic acid, pH

RESUSCITATION

- Loss of Na and water with accumulation of K in ECF = SHOCK.
- Resuscitation fluid should therefore exert same oncotic pressure as crystalloid content of blood.
- It should therefore resemble plasma which is ECF
- Lots of fluid is required often.

RESUSCITATION

- They must be plasma volume expanders.
- Contain the same electrolytes as ECF.
- Some energy source (dextrose).
- Rapid expansion of the intravascular space.
- Correction of the accompanying acidosis.

BALANCED SALT SOLUTIONS

- **Ringer's lactate**
 - 19th century physician.
 - developed his solution to replace plasma in frogs hearts hence low sodium.
 - in 1930's Hartmann replaced some of NaCl with Na lactate.
 - But still hypotonic.

RINGER'S LACTATE

- All the essential electrolytes to resuscitate.
- Buffering agent (lactate) helps to reverse the mild metabolic acidosis.
- Modern Ringer's lactate has the original amounts of Na,Ca,K.

PLASMALYTE L

- Contains lactate but no calcium.
- Important especially if using blood.
- No addition of bicarbonate.

PLASMALYTE B

- Addition of bicarbonate - readily useable by the body and helps to combat acidosis.
- Developed as an alternative to Ringer's as high lactate = poor outcomes.
- Calcium is removed (precipitates with bicarb-chalk).
- In glass as CO_2 rapidly diffuses thru plastic.

RESUSCITATION FLUIDS

- All the mentioned fluids are isotonic.
- Can therefore be infused in fairly rapid and large amounts with no adverse sequelae.
- If used in true cases of hypovolaemia.

REUSCITATION FLUIDS

	Ph	Osm	Na	K	Cl	Ca	Mg	Acet	Lact	HCO ₃	Dex	Kj/Cal
Ringer's	6.5	279	131	5.4	111	2			29			
Plasma L	6.5	273	131	5.4	107				29			
Plasma B	7.4	273	130	4	109		1.5			28	50	800
Hydroliet	5	548	130	5.4	108	1.8	1.5	29			50	800

REPLACEMENT THERAPY/REHYDRATION

- In addition to meeting maintenance needs and correcting moderate to severe deficits, concurrent losses must also be replaced.
- Concurrent losses = losses of water and electrolytes due to:
 1. Failure to provide adequate iv fluids (resusc/maintenance).

REPLACEMENT

2. Vomiting, gastric or intestinal suctioning.
3. Fistulae - colonic or intestinal.
4. Colostomy and enterostomy.
5. Diarrhoea and abnormal sweating.
6. Failure to eat and drink.

REPLACEMENT FLUIDS

- Maintenance fluids do not supply the additional free water and electrolytes required to replace concurrent losses.
- Essential to replace such losses.
- Must be done prior to starting any maintenance therapy.

REPLACEMENT FLUIDS

EXAMPLES



- **Dehydration**
- Condition requiring deficit replacement
- Goal is to normalise both fluid volume and electrolyte concentration.
- Thereafter maintenance therapy will maintain the patient in balance.

DEHYDRATION

- First assess the severity of the dehydration i.e. which and how much fluid.
 - **mild**: history, thirst, dryness of mouth
4% loss of body water (2.81)
 - **moderate**: marked thirst, dry mucous membranes, mild loss of skin elasticity
6% loss of body water (4.21)

DEHYDRATION

- **severe**: apathy, stupor, dry, skin lax, circulatory collapse.

8% loss of body water (7,6l)

- All will be accompanied by varying degrees of sodium loss (150-300mmol).

REPLACEMENT SOLUTIONS

	ph	Osm	Na	K	Mg	Cl	Lact	Phosp	Dex	kj
0.45%NaCl	5.5	154	77			11				
GRS	4	514	103	15		118			50	840
1/2 Darrow	5	434	61	17		51	27		50	840
Electrolyte 2	5	723	62	25	3	50	25	7	100	1680
0.9%NaCl	5.5	308	154	154		154				

MILD DEHYDRATION

- Sodium Chloride 0.45% (1/2 normal saline)
- General Replacement Solution (0.45% NaCl + dextrose 5%)
- Most commonly used.
- Electrolyte no 2 - hypotonic electrolyte content
 - aid in mild fluid deficits.

MODERATE DEHYDRATION

- Half-strength Darrows
- Electrolyte no 2
- Balanced salt solutions.
- These contain lactate/bicarbonate and will aid in counteracting the acidosis.


SEVERE DEHYDRATION



- Normal saline.
- Balanced salt solutions.
- Both will restore volume and sodium.

REPLACEMENT OF ONGOING ABNORMAL LOSSES

- IV fluid must replace ongoing losses (surgery, haemorrhage, burns, fistulae, ostomies, vomiting).
- Ideal is to replace as losses occur, no deficit to develop.
- Replacement must continue until medical or surgical therapy stops losses.
- In no way reduces need for maintenance.


- 
- Quantity and composition of lost fluid must be accurately estimated.
 - Replacement fluid must be chosen which closely mimics lost fluid.

GIT LOSSES

- Huge amounts of fluid lost.
- Must be high in Cl and K.
- **General replacement solution** is most suitable.
- **Normal saline** can be used - beware as no K
- **HYPERNa**

FLUID THERAPY DURING SURGERY

- Goal is to correct circulating volume deficit as it occurs.
- Beware of shifts between compartments.
- Prior - losses $>$ fluid intake d/t illness, injury, pyrexia, vomiting
 - npo, delayed surgery.

- 
- During - blood loss
 - evaporation exposed gut
 - ventilation with dry gases
 - third spacing.
 - We can see that considerable volumes of fluid may be required, even if the blood loss is not severe.

DOSAGE OF FLUIDS IN SURGERY

- Major surgery : 7 -10 ml/kg/hour
- Minor surgery : 3 - 5 ml/kg/hour

BALANCED SALT SOLUTIONS

- Successfully expand and maintain circulating volume if blood loss is not severe.
- Not confined to iv space.
- Will have to use a colloid if loss is severe.
- Mimics ECF by containing major electrolytes.

BALANCED SALT SOLUTIONS



- They will:
 1. Restore effective circulating volume.
 2. Replace extracellular losses and shifts.
 3. Combat metabolic acidosis and improve perfusion.

BALANCED SALT SOLUTIONS

	ph	Osm	Na	K	Ca	Mg	Cl	Acet	Lac	Bicarb	Dex	kj
Plasmalyte B	7.4	273	130	4		1.5	109			28		
Plasmalyte L	5.5	551	131	5			107		29		50	840
Hydroliet	5	548	130	5.4	0.8	1.5	108	29			50	840
Ringer's	6.5	279	131	5.4			111		29			

MAINTENANCE THERAPY

- Supply the water, electrolytes and calories.
- Replacing insensible losses through skin, lungs, urinary excretion.
- Patients unable to ingest food po will need iv maintenance therapy.
- Dictated by basal metabolic rates.
- Increased metabolism = increased maintenance. (physical activity, pyrexia)

AIM OF MAINTENANCE THERAPY

- Provide adequate water, electrolytes and calories to maintain a patient in a balance over a short period (2-5 days).
- Important to include replacements.
- Normal loss = 2.5-3.0l/24 hours
- Lung/skin evaporation 500-1000ml
- Urine output 650-1800ml
- Faeces 50-200ml

DAILY ELECTROLYTE REQUIREMENTS

- Na	100mmol
- K	75mmol
- Cl	120mmol
- Mg	8mmol
- Ca	5-12.5mmol
- Calories	1600 (6700 kilojoules)
- Protein	30g
- Vitamins	B complex, Vit C

FLUID REQUIREMENTS

- 2500-3000ml fluid per day plus daily requirements of electrolytes and calories.
- Increased in pyrexia and high BMR.
- Decreased in CCF, renal failure
- Adult daily requirements:
 - 30-40ml/kg/day

GUIDE TO ESTIMATE DAILY FLUID MAINTENANCE

- 1kg - 10kg 100ml/kg/day
10kg=1000ml
- 11kg - 20kg 50ml/kg/day
20kg=1000ml+500ml=1500ml
- 21kg - 70kg 20ml/kg/day
70kg=1000ml+500ml+1000ml=2500ml

INDICATIONS FOR MAINTENANCE THERAPY

- Normally high in K, low in Na and Cl.
- Patient must be stable and fully resuscitated.
- Mild electrolyte imbalances can be corrected with maintenance solutions.
- Severe deficiencies may require additional supplementations e.g. K

WHICH SOLUTION TO CHOOSE



- Patient's clinical condition important.
- They should:
 1. Meet daily requirements of Na, K, Mg.
 2. Supply close to minimum daily calorie requirements.

MAINTELYTE



- Best meets criteria
- 3l provides close to daily requirements.
- Has additional Cl.
- No buffers, therefore will not contribute to postsurgical alkalosis.

GENERAL MAINTENANCE SOLUTION



- If lower Na required.
- No Mg.
- 200 calories only.

ELECTROLYTE NO 2

- Mild rehydration solution and for cell repair e.g. post diabetic coma.
- High Na concentrations.
- Contains 2 buffers (lactate, phosphate)- useful to correct acidosis.
- If lower Cl required.

MAINTENANCE SOLUTIONS

	ph	Osm	Na	K	Mg	Cl	Lact	Bicar	Dex	kj
GMS	4	383	26	27		53			50	840
Electrolyte 2	5	723	62	25	3	50	25	7	100	1680
Maintelyte	4	683	35	25	3	65			100	1680

PAEDIATRIC INTRAVENOUS THERAPY



- Number of unique features.
- IV requirements of neonates differ from normal paediatric patients.
- Essential to consider neonate needs separately.
- Challenging and often difficult to approach.

PAEDIATRIC FLUID THERAPY

- To maintain electrolyte balance by iv in any infant it is essential to:
 1. Replace normal losses i.e. maintenance.
 2. Replace any previous deficits by increased losses or decreased intake.
 3. Replace ongoing losses by stools if abnormal (and urine output).

INFANTS WHICH REQUIRE IV THERAPY

- Cardiorespiratory disease.
- Premature infants < 32 weeks gestation.
- Hypoglycaemia.
- Infections.
- Git abnormalities or disease.

MAINTENANCE FLUID AND ELECTROLYTES

- **Water** - 150ml/kg/day.
 - can increase to 180-200ml/kg/day.
 - depend on clinical condition and prematurity.
 - in early neonate, renal immaturity, therefore beware of large volume loads (overload).
 - first 24hours 60ml/kg and increase.

MAINTENANCE REQUIREMENTS

- **Calories:**
 - Related to cell mass and number.
 - 100-120 calories/kg/24hours.
 - If low birth weight increased calories req..
 - Increase temp of 1c= increase caloric requirements by 12%.

CALORIES



- 1kg - 10kg 100 cal/kg
10kg=1000calories
- 11kg - 20kg 50cal/kg
20kg=1000+500=1500calories
- 21kg - 30kg 25cal/kg
30kg=1000+500+250=1750calories

ELECTROLYTE REQUIREMENTS

- Na 1-2.5mmol/kg
- K 2mmol/kg
- Ca 0.5-1mmol/kg
- Mg 0.15mmol/kg
- Cl 1.8-4.3mmol/kg
- Phosphate 0.4-0.8mmol/kg

PAEDIATRIC RESUSCITATION

- Large volume losses rapidly result in circulatory collapse.
- Ultra important to restore iv volume ASAP.
- Isotonic electrolyte solution ideal
 - Ringer's
 - Plasmalyte B
 - blood if needed
- Beware of lactate, bicarb if in respiratory distress.

INFANTILE DEHYDRATION

- Gastroenteritis, dysentery, pyloric stenosis, intestinal obstruction.
- Diarrhoea is very important cause of water and electrolyte loss, together with vomiting.
- Rapid decrease in ECF.
- Always treat it aggressively
- 5,10, and especially $> 10\%$.

AIM



1. Expand ECF volume.
2. Correct/prevent acidosis.
3. Correct intracellular dehydration and electrolyte abnormalities.
4. Provide normal maintenance requirements.
5. Replacement therapy must continue if ongoing abnormal losses.




6. Always resuscitate infants immediately.

7. Correct over 24 hours or if patient very ill over 48 hours.

- **Half-strength Darrows** - hyper, hypo or isotonic dehydration.

- 150ml/kg/24hrs ma

- 50-100ml/kg/24 rep

- 
- If severe dehydration:
 - Add **Normal saline 0.9%** - 20ml/kg/6hours
 - To restore renal function, once circulation restored.

MAINTENANCE

- Continue until infant can obtain adequate nutrition via oral route.
- Reassess every 2 hours.
- Composition of **Neonatalyte** complies best.
 - Carries less Na.
 - It is a short term maintenance solution.
 - Not a replacement, it is only rehydration.

PAEDIATRIC MAINTENANCE FLUIDS

	Na	K	Mg	Ca	Cl	Phosp	Lact	Glucose	kJ
0.2% saline 5% dex	34				34			50	840
1/2 Darrows	61	17			51		27	50	840
Neonatalyte	20	15	0.5	2.5	21	3.75	20	100	1680

PERCENTAGE OF DAILY REQUIREMENTS


	Requiurements	0.2%saline5%dex	1/2 Darrow s	Neonatalytes
Volume	750	750	750	750
Na	12.5	26	46	15
K	10		13	11
Mg	0.75		1	0.4
Ca	2.5-5.0			2
Cl	9-21.5	26	38	16
Phosphate	2.0-4.0			3
kj	2520	630	630	1266
Calories	600	150	150	300

COLLOID SOLUTIONS

- Osmotically active - high molecular weight.
- Solutions are maintained intravascularly.
- Intravascular half life = 3-6 hours.
- (Crystalloid half life = 20-30 minutes).
- Substantial cost.
- Occasional complications.
- Above two sometimes limit use.

INDICATIONS

1. Fluid resusc. In severe fluid deficits (eg haemorrhagic shock) prior to blood availability for transfusion.
2. Presence of severe hypoalbuminaemia or diseases of large protein loss e.g. burns.
3. In conjunction with crystalloids if fluid load exceeds 3-4l prior to transfusion.

- 
- Several available.
 - Derived from either plasma proteins or synthetic glucose polymers.
 - In isotonic electrolyte solutions.

DEXTRANS



- Dextran 70, Dextran 40.
- Problems: - antiplatelet
 - associated with renal failure
 - can interfere with blood typing
 - antigenic
 - anaphylactic reactions
- Dextran 1 hapten binds with dextran antibodies.

HYDROXYETHYL STARCHES

- 6% and 10% solutions.
- Mw 450000 daltons.
- Small molecules eliminated by the kidney.
- Bigger ones, broken down into amylase.
- Highly effective as plasma expanders.
- Less expensive than albumin.

HYDROXYETHYL STARCHES



- Non antigenic.
- Anaphylaxis very rare.
- Coagulation not affected up to 2l of fluid given.