Intravenous Fluids: In the ER and on the floor

MEValletta, MD

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Resident Core Conference Lecture Series

Objectives

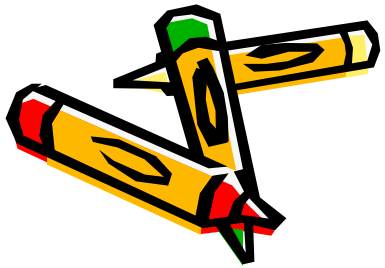
- Understand appropriate fluid resuscitation
- Understand appropriate fluid choice- IV versus oral, and type of IVFs
- Learn factors that will likely impact choice

Type of IVFs

IV fluid(meq/L)	Na	Cl	K	Glu	Bicarb
D5W	0	0	0	50g/L	0
D5W ¼ NS	34	34	0	50g/L	0
D5W ½ NS	77	77	0	50g/L	0
LR	130	109	4	0	28
D5 LR	130	109	4	50g/L	28
D5 0.9% NS	154	154	0	50g/L	0

Electrolyte free water (EFW) in Parenteral Fluids

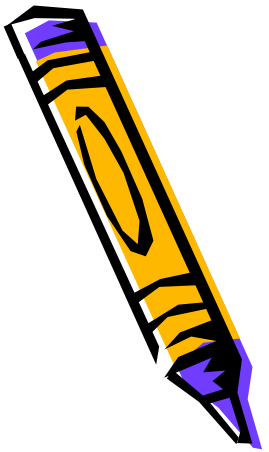
IV fluid	Na	Osm (mOsm/L)	Tonicity	% EFW
D5W	0	252	0	100
D5W ¼ NS	34	321		78
D5W ½ NS	77	406	150	50
LR	130	273		16
D5 LR	130	525		16
D5 0.9% NS	154	560	308	0



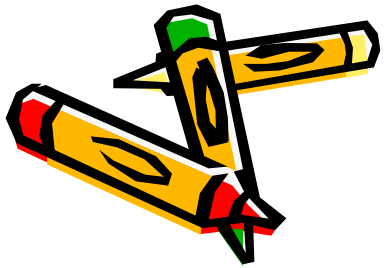
Osmolarity vs Tonicity

- Osmolarity is the number of osmoles of solute per liter of solution
- Tonicity is the total concentration of solutes which exert an osmotic force across a membrane in vivo
- Dextrose is not considered to have an osmotic effect because it is rapidly metabolized in blood
- For substances that cannot cross cell membranes, tonicity is practically identical to osmolarity

What we all learned: Holliday & Segar Method



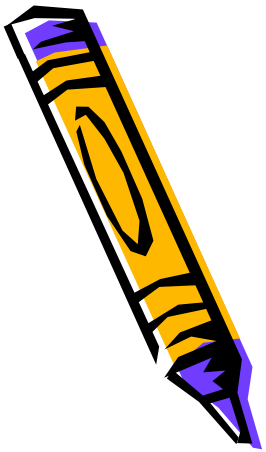
- Pediatrics 1957; 19: 823-32
- Maintenance water needs related to energy expenditure requirement, related to weight (<10kg, 10-20kg and >20kg)
- Na of 3 mEq /K 2 mEq/ Cl 2 mEq/ 100 kcal / 24 hours
- Equal to about 30 mEq of Na in 1000 ml which is roughly $\frac{1}{4}$ NS
- Na and K recommendations arbitrarily based on the composition of electrolytes in breast and cow milk
- Fluid calculations based on keeping urine osmolality of 400 mOsm/kg/H2O believed to be ideal



Electrolytes based on 100kcal

Wt-kg	Fluid ml	Na-3 meq/100 kcal	Na-meq/k	K infused at 20 meq/k	K-meq/k
5	500	15	3	10	2
10	1000	30	3	20	2
20	1500	45	2.25	30	1.5
30	1700	51	1.7	34	1.1
40	1900	57	1.43	38	0.95

Maintenance IV Fluid in Children

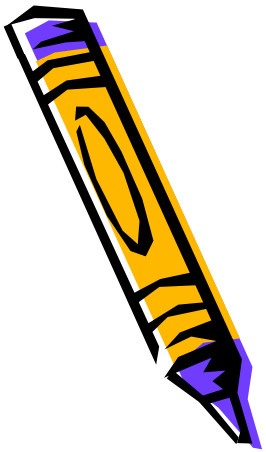


- Example: 10 kg infant
- Fluid: 100 ml/kg/d = 1000
- Na 3 mEq /kg/d = 30 mEq
- IV fluid **D5 ¼ NS** = 34 mEq of Na in 1 liter of D5W

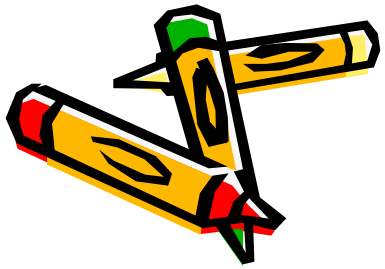
IVF Calculations

- K approximately 2 meq/k/d
- 10 kg child=20 meq/k/d
- 20meq/1000= 20meq/L of KCl
- So per Holliday/Segar method: D51/4 NS with 20meq/L KCL at 40 ml/hour

Maintenance IV Fluid in Children



- 40 kg child
- Fluid: ~ 2000 ml
- Na: 3 mEq/ kg = 120
- 120 mEq of Na in 2 liters=60meq/L
- **D5 ½ NS** = 75 mEq of Na in 1 liter of D5W



IVF Calculations

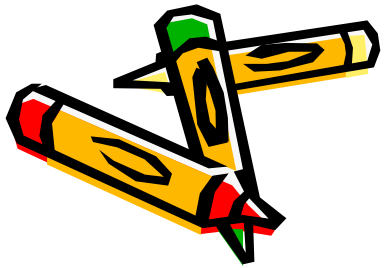
- K again 2 meq/k/d=80meq/k/d
- 80meq/2L= 40 meq/k/1L
- Start though with max of 20meq/L of KCL (and patient must be urinating) unless patient is hypokalemic because of risks associated with hyperkalemia
  - Remember although declining K requirement with weight, K frequently depletes with Na in sick kids
  - Additionally, acid base status affects intra-extracellular shifts of K
- So for this child: D5 ½ NS with 20meqKCL/L at 80ml/hour

IVF Calculations

- Diarrheal Dehydation
  - Na deficit likely to be 8-15 meq/k depending on whether iso or hyponatremic
  - K deficit can likewise be 8-15 meq/k
- May see similar requirements in infants with pyloric stenosis
- Never infuse K at >1 mEq/k/hour, if exceeds 0.5 mEq/k/hour need cardiorespiratory monitoring

Dehydrated Patients

- Are they dehydrated?
- Gold standard is measurement of acute weight loss!
- Practically we rely on clinical assessment



Suggested Approach to Clinical Assessment

- PPV for any of the clinical criteria were low (0.17 to 0.57)
- Whereas NPVs were generally high (0.93 to 0.99)
- Both because of the low prevalence of dehydration
- However, four of the ten clinical parameters were found to be significantly associated with a fluid deficit of 5% or more dehydration

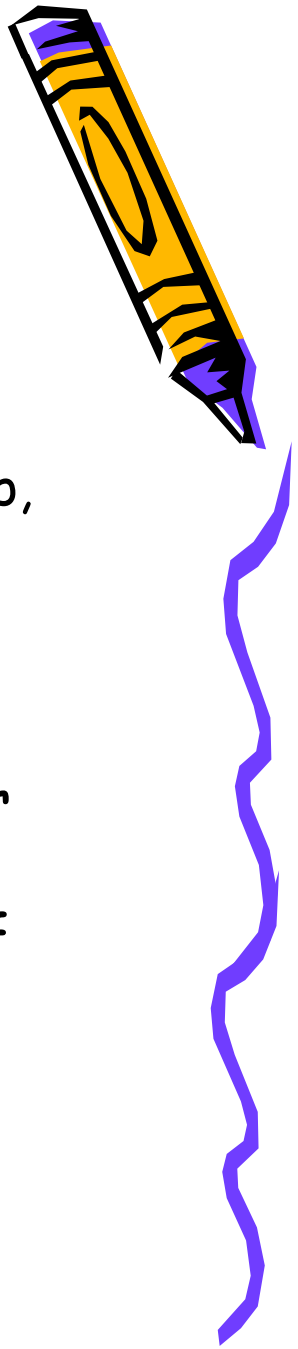
Validity and Reliability of Clinical Signs in the Diagnosis of Dehydration in Children Gorelick MH et al Pediatrics 1997; 99.5.e6

Clinical Assessment of Dehydration

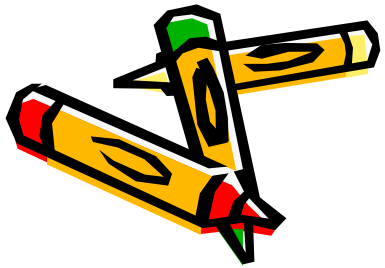
- 10 Clinical Parameters

•Decreased skin elasticity	•Dry mucous membranes
•Cap refill >2 sec	•Sunken eyes
•General Appearance	•Abnormal radial pulse
•Absent Tears	•Tachycardia (HR>150)
•Abnormal respirations	•Decreased UOP

Suggested Approach to Clinical Assessment



- Evaluate four of the ten:
  - Abnormal general appearance-lethargic, drowsy, limp, cold, etc.
  - Capillary Refill >2 sec
  - Dry mucous membranes
  - Absent tears
- Presence of any two indicates deficit of 5% or more
- Presence of three or more indicates deficit of 10% or greater
- If less than 2, consider ORT therapy!



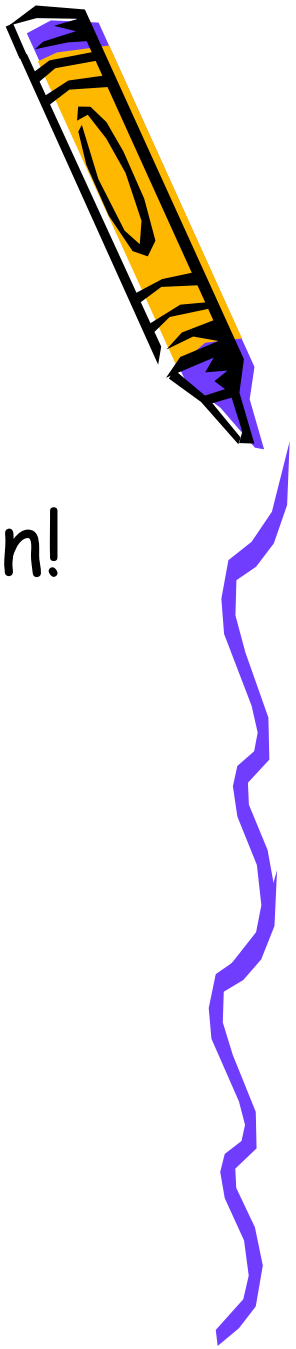
Resuscitation

- Always isotonic fluids!!!-Normal Saline
- Bolus 20ml/kg (unless neonate than only 10ml/kg)
- REASSESS! REASSESS! REASSESS!
- Studies have demonstrated reduced ADH levels with adequate initial fluid resuscitation

Post-Resuscitation

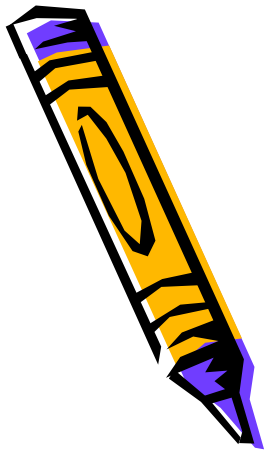
- Need to assess BMP
- Is patient hypo, iso or hypernatremic?
- Is the patient acidotic?
- What is underlying acute illness?
- Are there any complicating aspects or underlying chronic medical conditions?

Pitfall with the Holliday Segar method

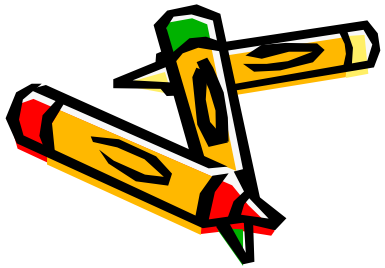


- Based upon fluid and electrolyte requirements of HEALTHY children!
- Accordingly, does not take into account increased ADH levels in hospitalized children

Oddball Out: The Hypernatremic Dehydrated Patient

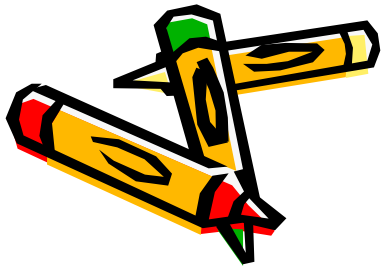


- These are the patients who need free water!
- They may not appear as clinically dehydrated as they are because they are maintaining intravascular volume
- Skin may be doughy in texture
- If unsure how acutely the patient became hypertonic, do not correct more quickly than 0.5meq/hour or 10-12 meq over 24 hour period

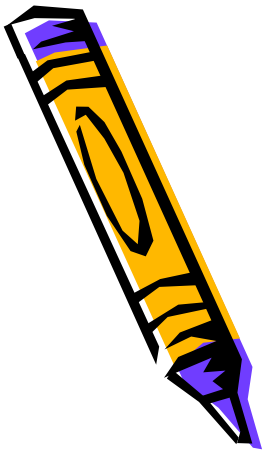


The Hypernatremic Dehydrated Patient

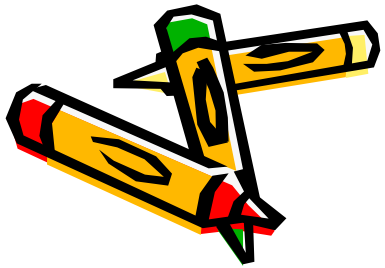
- In order to decrease Na by 1 mEq/L may estimate 4ml/kg
- Free Water Deficit= 4ml/kg x preillness weight x (Current Na –goal Na)
- Replace $\frac{1}{2}$ FWD with solute fluid deficit and maintenance over 24 hours and REASSESS



Hypernatremic Dehydrated Patient: Example Calculation

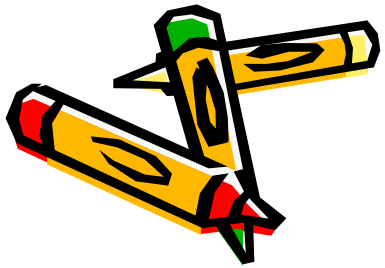


- Determine % dehydrated based upon clinical grounds
- 10 kg toddler estimated at 10% dehydrated
- Preillness weight=Current weight/(1-%dehydrated)
- 10kg/1-0.1 or 10kg/0.9 = 11kg
- Weight down 1kg (1 kg=1L fluids)
- Deficit of fluids equals 1L but how much of that is free water deficit and what if he got a bolus of NS?



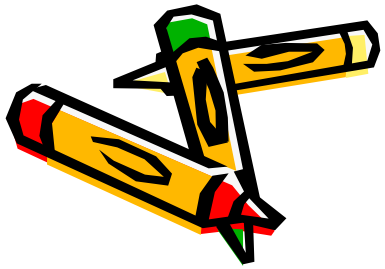
Hypernatremic Dehydrated Patient: Example Calculation

- Patient received 20ml/kg bolus or 200ml NS
- Serum Na 155
- FWD=4ml x 10kg x (155-145)=400ml
- Total fluid Deficit=1000 of which 400ml is FWD so solute fluid deficit is 600ml
- 600 solute fluid deficit minus 200ml NS bolus so now remaining deficit is 400 solute fluid



Hypernatremic Dehydrated Patient: Example Calculation

- May calculate Na and K solute deficit as follows:
  - 0.4 (Extracellular compartment) x 0.4L (solute deficit) x 145 (normal Na)=23mEq
  - 0.6 (Intracellular compartment) x0.4L (solute deficit) x 150 (normal intracellular K)=36mEq



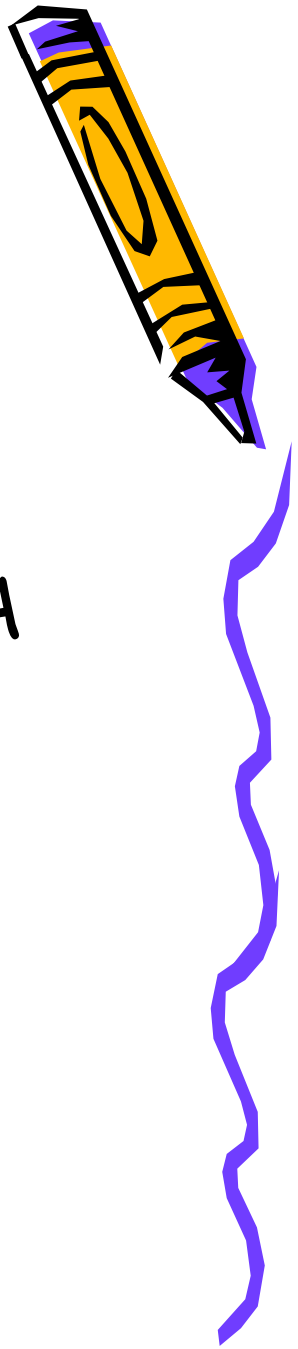
So-o-o-o

- 24 hour maintenance 10kg x 100ml/kg= 1000ml
- Plus ½ FWD (½of 400)=200ml
- Plus solute deficit of 400ml
- Total fluids for 24 hours 1600 or 67ml/hour

So-o-o-o

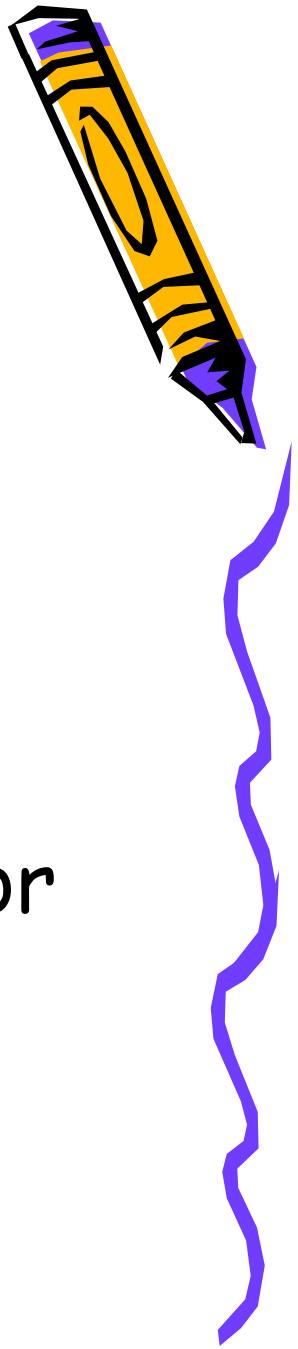
- Na 23 meq deficit plus 33 meq (maintenance of 3 x 11kg)=56meq/1600ml or 35meq/L
- K 36 meq deficit plus 22 meq (2 x 11kg)=58meq/1600ml or 36meq/L
- Appropriate initial fluids would be D5 $\frac{1}{4}$ NS with 20-30meq KCL/L at 65 ml/hour
- Recheck Na/k Q4hours to follow initially

The New Debate: The role of isotonic maintenance fluids



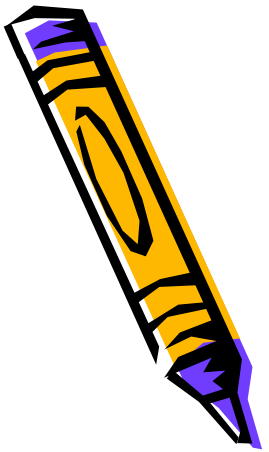
- Moritz and Ayus: Prevention of Hospital Acquired Hyponatremia: A case for using Isotonic Saline Pediatrics 2003; 111; 227-230.

The Risk of Hypotonic fluid infusion with elevated ADH levels

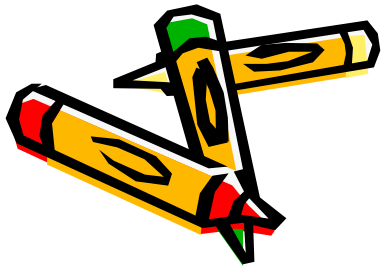


- Acute hyponatremia iatrogenically caused
- Hyponatremic encephalopathy with resultant neurological compromise or even death

Etiology in the inpatient setting



- Sick kids have impaired ability to excrete free water
- Sick kids have nonosmotic stimulus for ADH production
- Peculairly at risk because sick kids have big brains and small skulls: Adult brain size by age 6. Adult skull size though not until age 16!



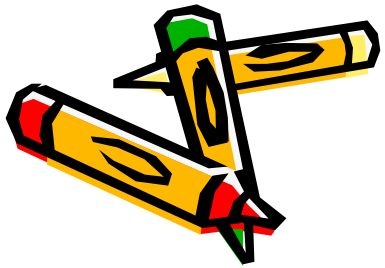
Excess ADH-Maybe inappropriate *or* appropriate

Decreased ECV

- **Hypovolemia-Potent stimulus for ADH**
  - **GI losses**
  - Renal Losses: Salt wasting nephropathy (cisplatin and ifosfamide nehphrotoxicity) diuretics, cerebral salt wasting, hypoaldosteronism
- Edema forming states: CHF, cirrhosis and nephrosis, hypoalbuminemia
- Hypotension

Excess ADH- Inappropriate

- CNS Disturbances: Meningitis, encephalitis, brain tumors, CHI
- Pulmonary Dz – RSV, asthma
  - in this setting, however the etiology is often related to cardiac compression by lungs
  - Perceived as lower intravascular volume
- Cancer: Lymphoma and Leukemia



Excess ADH- Inappropriate

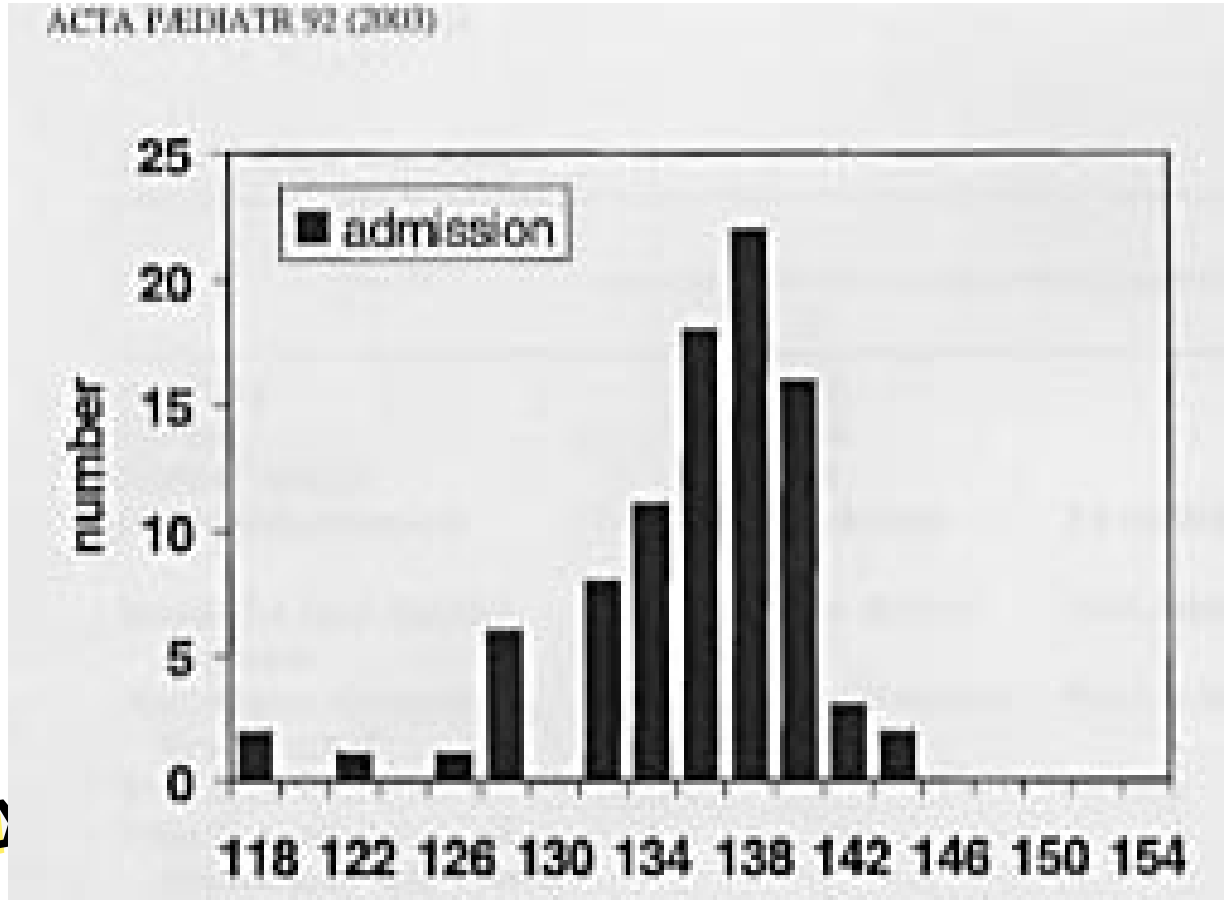
- Meds:
  - Cytoxan (cyclophosphamide)-Increased renal effects of ADH vs direct tubular effect (ADH levels do not rise)
  - Vincristine-Significantly increased levels of ADH
  - Morphine
  - Anesthetics
- Nausea, emesis, pain stress
- Post-Op state

Incidence of Hyponatremia and hyponatremic seizures in severe RSV bronchiolitis

- Median age 6 weeks
- Hyponatremia at time of admission to ICU occurred in 33% (30/91) of cases
- 4% were admitted following hyponatremic seizures
- 3 of the 4% had received D5 0.25NS at 100 to 150 ml/kg

- Acta Paediatr 92: 430-434, 2003

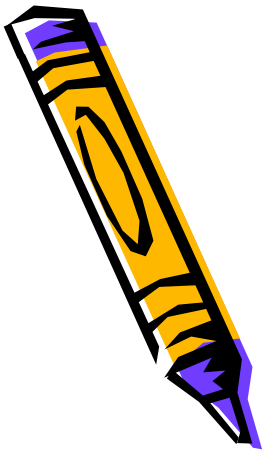
Serum Na in RSV infants on Admission



Hyponatremia and RSV

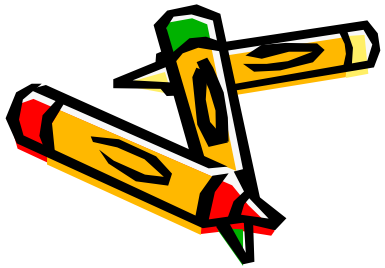
- ADH levels markedly elevated: correlates with the degree of air-trapping and hypercapnia.
- ADH levels decrease as the disease process resolves
- Stimulus is non-osmotic.

Hospital Induced Hyponatremia

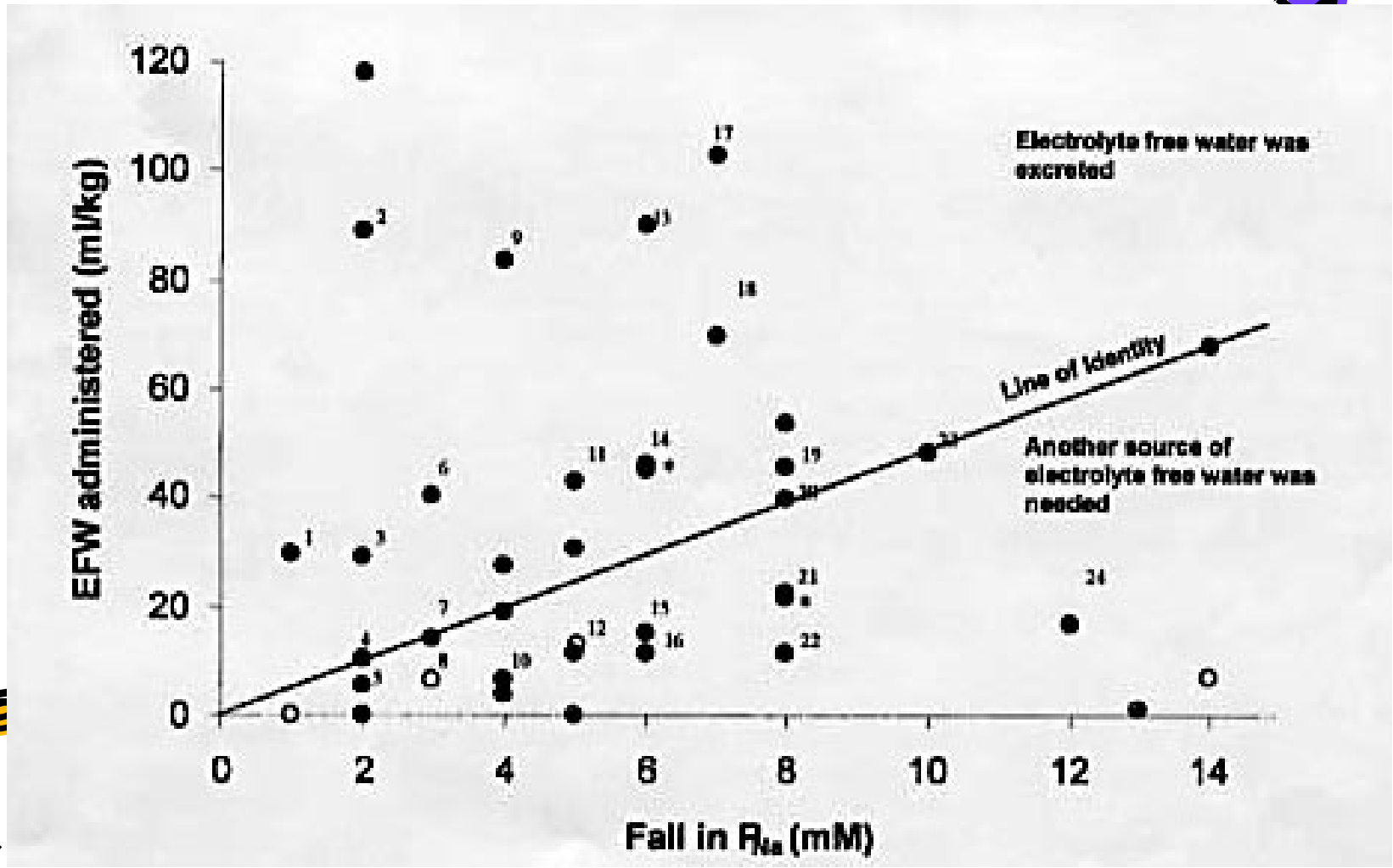


- 97 out of 432 patients had hyponatremia with serum Na <136
- 40 of 97 developed *hospital acquired* hyponatremia
- Interestingly, most received sufficient EFW to account for the drop in serum Na, however, a number did not!

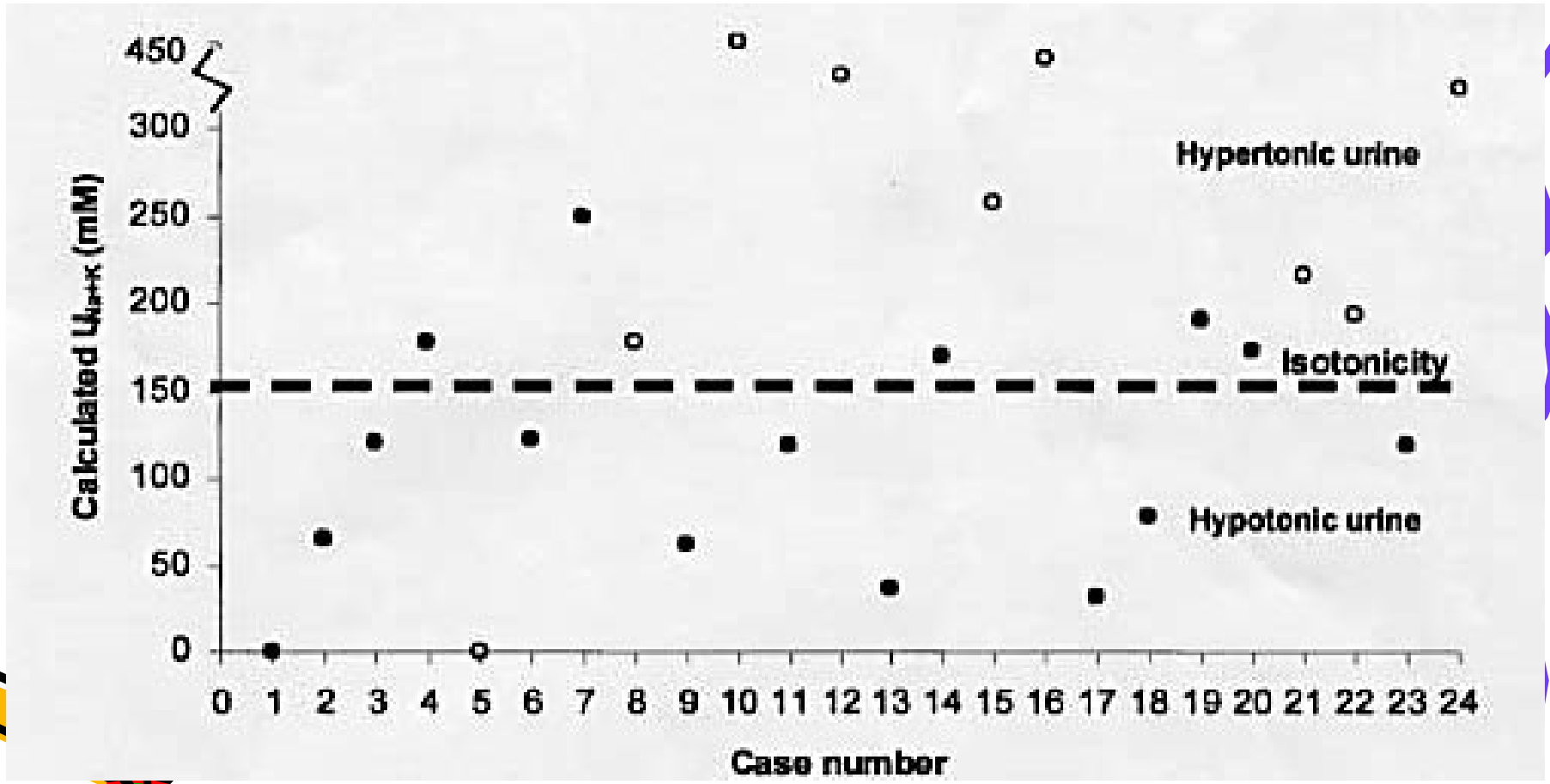
Acute Hyponatremia related to intravenous fluid administration in hospitalized children: an observational study *Pediatrics* 2004;113:1279-1284
(Hoorn, Geary, Robb, Halperin, Bohn)



Relationship between EFW administration and fall in P Na

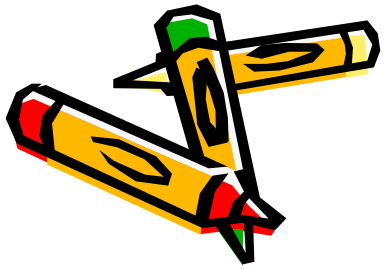


Calculated Urine Na Concentration



Hospital Induced Hyponatremia study

- Most patients with a decrease in serum Na could be explained by infusion of hypotonic fluids
- Where it could not be explained by EFW, patient could have had an occult water source, or alternatively *desalination* with hypertonic urine
- Again suggesting high ADH levels as culprit



Desalination

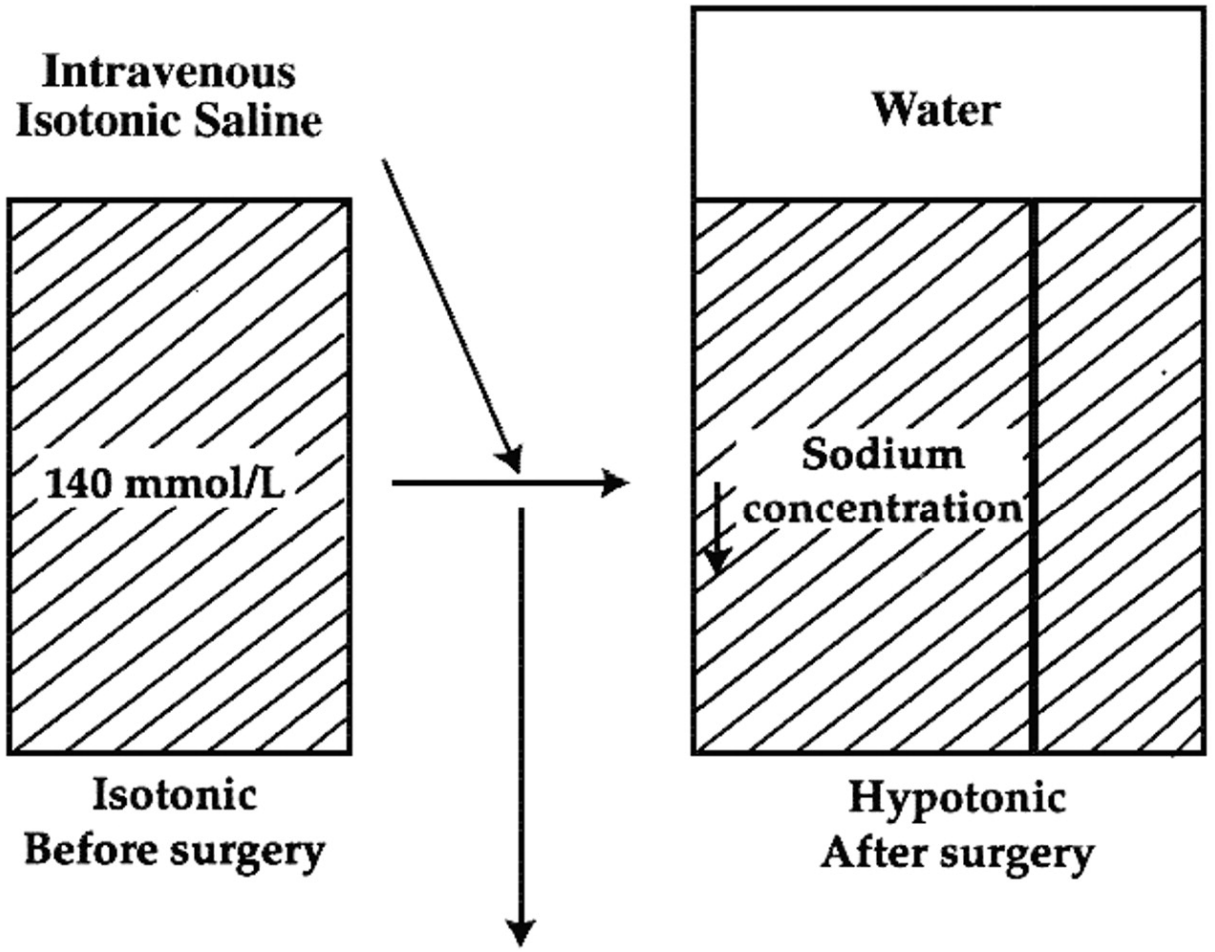
- Even isotonic fluids can generate free water by the kidneys!
- Post op hyponatremia occurred within 24 hours despite infusion of only isotonic fluids

- Postoperative Hyponatremia despite Near-Isotonic Saline Infusion-A phenomenon of Desalination *Ann Intern Med* 1997; 126:20-25

Desalination

- Desalination occurs with the loss of hypertonic urine.
- ADH causes retention of EFW which forms a result of hypertonic urinary losses

The desalination process



Steele, A. et. al. Ann Intern Med 1997;126:20-25

Annals of Internal Medicine

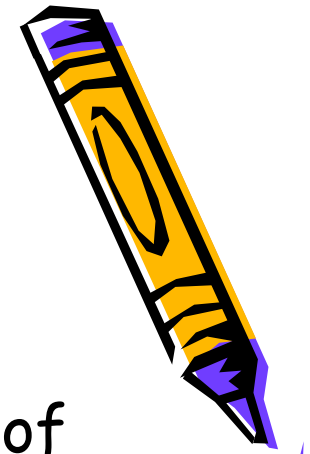
Management of Desalination

- Hypotonic iv fluids *should not be given* during or immediately after surgery
- Give only the minimum volume of isotonic fluid needed to maintain hemodynamics perioperatively
- Check serum Na if urine is hypertonic (SpGr >1.020)
- Hypertonic solution administration until urine Na and K decrease

Management of Desalination

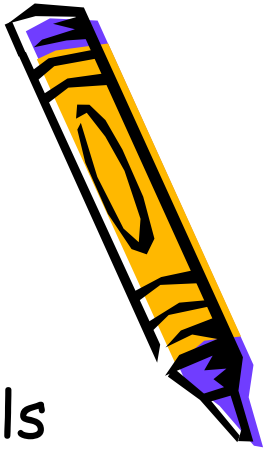
- If hyponatremic and still having large volumes of hypertonic urine:
- Option 1: Infuse saline solution with the same tonicity and flow rate as the urine
- Option 2: Administer a *loop diuretic* (thiazides would make it worse) or an osmotic diuretic such as urea

Are there Risks of Isotonic Fluid for Maintenance?



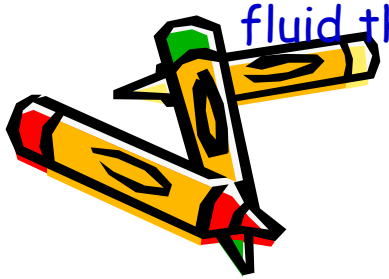
- Holliday and Segar propose a *theoretical* risk of hypernatremia-However, not proven.
- Moritz and Ayus note that NS as a maintenance fluid has not been demonstrated to cause hypernatremia
- Most common cause of hypernatremia in hospitalized kids is fluid restriction with FW losses (example DI)
- The additional chloride does act as fixed acid and may worsen acid base status

Are there Risks of Isotonic Fluid for Maintenance?



- 1990 randomized trial evaluating fluid protocols for children with meningitis
- Compared fluid restricted group who received hypotonic saline to fluid deficit replacement with maintenance using predominantly isotonic fluids
- Isotonic fluid group received approx 6mmol Na/k/d and had *normal serum Na*
- Hypotonic fluid group received approx 2 mmol Na/k/d and became *hyponatremic*

Normalization of plasma arginine vasopressin concentration when children with meningitis are given maintenance plus replacement fluid therapy. *J Pediatr* 1990;117: 515-22.



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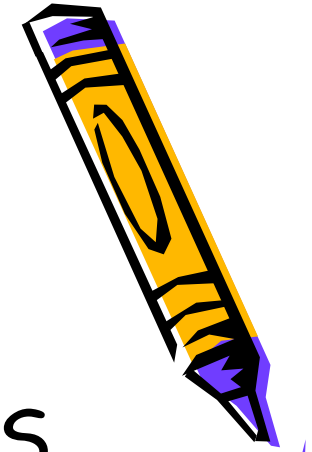
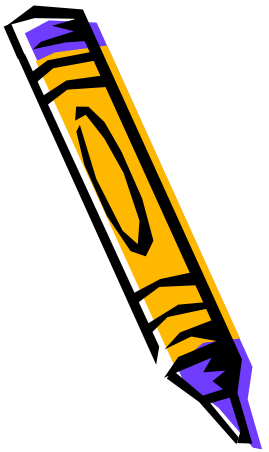


- Large volume resuscitation with NS of septic infants and kids (80-180 ml/k/d) did not cause hypernatremia

- Chasing the base deficit: hyperchloraemic acidosis following 0.9% saline fluid resuscitation. *Arch Dis Child* 2000; 278: F585-97

Holliday and Segar 2004 Commentary in response

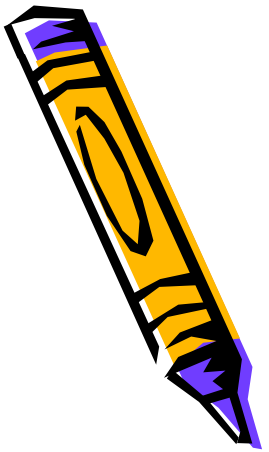


- Initially give children with marginal to moderate hypovolemia 20 to 40 ml/kg of 0.9% saline over 2-4 hours
- If hypovolemia more severe 40-80 ml/kg of 0.9% saline
- Maintenance fluid – May then give hypotonic fluids at maintenance rates if maintenance needs cannot be met by oral therapy
  - Acute Hospital Induced Hyponatremia in Children: A Physiologic Approach *J Pediatr.* 2004; 145: 584-87;
  - Isotonic Saline Expands Extracellular Fluid and Is Inappropriate for Maintenance Therapy *J Pediatr.* 2005; 115: 193-94.

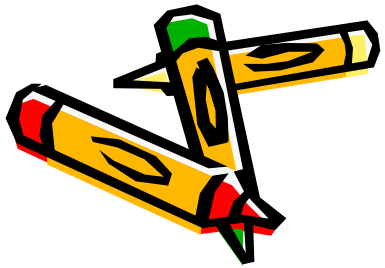
Hoorn, et al Approach

- Measure serum Na once resuscitation is complete
- If serum Na is <138 then do not infuse hypotonic fluids

Moritz and Ayus Approach



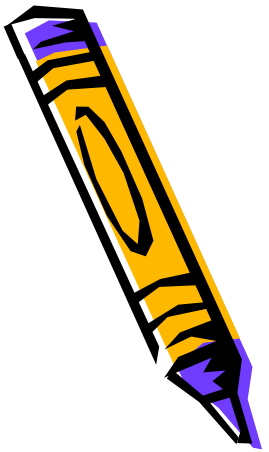
- Isotonic fluid for resuscitation and maintenance fluid regardless of their serum Na
- They note that the majority of patients who developed hyponatremia had a serum Na >137 and the 1 death occurred in a patient with Na 142
- Their conclusion, no hypotonic fluids unless FWD or ongoing free water losses!



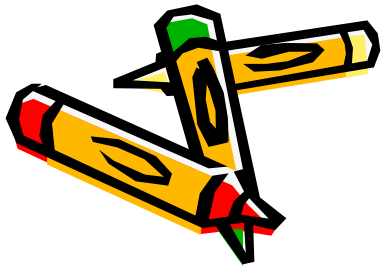
General Fluid Recommendations

- ONLY ISOTONIC FLUIDS LIKE NS or LR fOR FLUID BOLUSES!
- Check Na after fluid resuscitation.
- Make sure you have adequately resuscitated your patient.
- If Na less than 138 do not infuse hypotonic fluids.

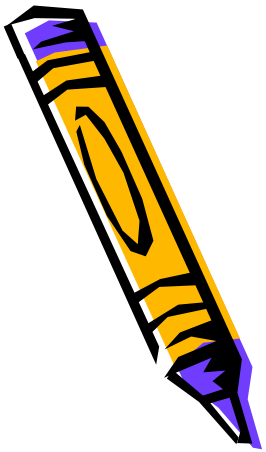
General Fluid Recommendations



- Do not give fluids when not needed.
- No role for D5 $\frac{1}{4}$ NS except in hypernatremic patients, neonates less than 30 days of life or CHF infants.
- Daily Weights/Fluid Balance with Strict Is and Os/ BP
- Exams repeated throughout the day!- Observe for signs of fluid overload.
- Frequent monitoring of electrolytes.



Which kids are at risk?



All hospitalized sick kids are at HIGH RISK for developing hyponatremia!

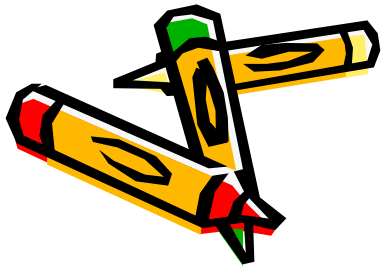
Remember IVFs are a drug!

Example Case Scenario

- Fussy 5 month old baby girl
- Wt 6.5 kg, HR 170, BP 77/40, RR 52, T37, cool extremities, decreased skin turgor, CR 3-4 sec, no tears, dry mucous membranes

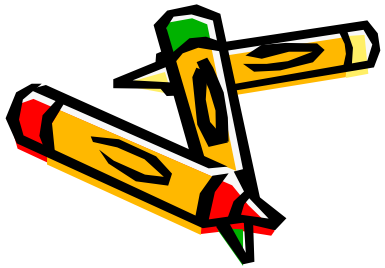
What is your assessment?

What is your initial management?



Case Progression

- Shock is present
- Emergency resuscitation-20ml/kg bolus of NS
- After total 40ml/kg, HR is 140, BP 85/40, easily palpable pulses, feet warmer, CR 2-3 sec
- Mom reports 2 day ho URI symptoms today with increased WOB, not wanting to feed, decreased UOP. Unremarkable PMH. Sick 4 yo sib at home.



Case Progression

- After bolus, infant with UOP
- Labs: Na 135, k 3.6 Cl100 HCO3 16 BUN 12 Cr 0.9 glucose 80

What do you estimate infant's deficit to be?

What fluids would you use?

Case Progression

- Deficit at least 10% to 15%
- Preillness wt= 6.5/1-0.1=7.2 to 7.6
- Deficit 0.7 to 1 kg or 700ml-1L
- Rule of thumb is 10ml/kg for each 1 percentage dehydrated…
- Subtract boluses of 260ml=440ml

Case Progression

- Deficit over first 8 hours
- 24 hour maintenance over the remaining 16 hours
- I would use NS for the first 8 hours because likely RSV and Na <138;
- As infant urinating would add 20 KCL or KAcetate/L since acidotic (Acetate converted to bicarb in normal liver);
- Then *reassess*
- Transition to po as soon as able!

THANK YOU!