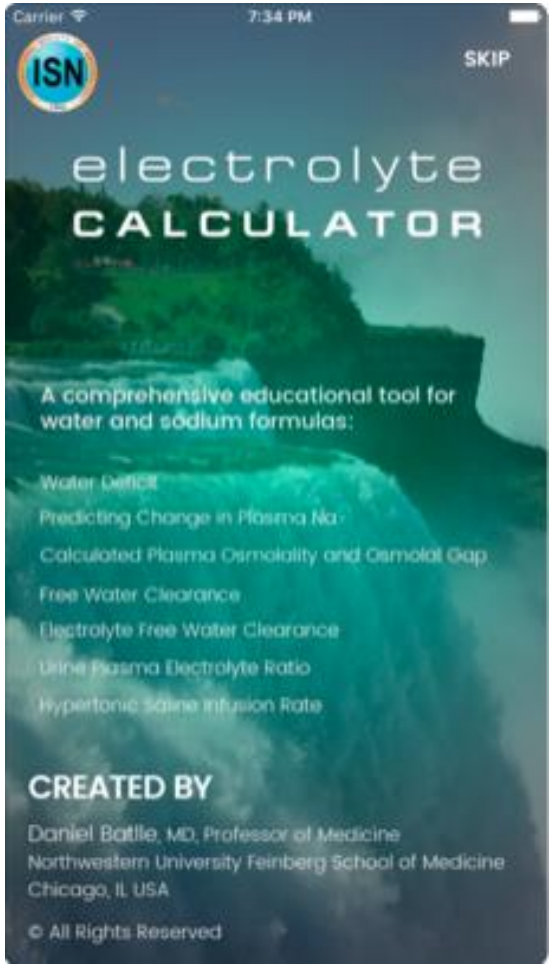


ISN

Electrolyte Calculator

A comprehensive educational tool for water and sodium formulas

Available on the iTunes App store and Google Play - Search for "Water and Sodium Formulas"

A case of dehydration

An 88 yo male with chronic dementia develops increasing confusion in the nursing home. His BP is 132/82 mmHg.

Plasma Na 170 mEq/L, plasma K 4.2 mEq/L. glucose 100 mg/dL, uOsm 800 mOsm/L, weight 70 kg.

Estimating his TBW as 50% of body weight, what is his current estimated water deficit?

Water Deficit Calculation

$$\textit{Water Deficit} = \textit{TBW} \times \left(\frac{PNa^{+}}{140} - 1 \right)$$

Water deficit = 35Lx ([170mEq/L /140 mEq/l] -1)= **7.5L**

Predicting plasma Na+ during correction of water deficit

One can estimate how much will the plasma Na^+ decrease after 1L of 5% dextrose infusion:

- Plasma Na 170 mEq/L,
- Plasma K 4.2 mEq/L.
- weight 70 kg
- **BP is 132/82 mmHg**

Predicting plasma Na+ during correction of water deficit

calculate the change in plasma Na?

$$\text{Change in } PNa^{+} = \left[\frac{(\text{Infused Na+} + \text{Infused K+}) - PNa+}{TBW+1}\right]$$

$$\text{Change in } PNa^{+} = \left[\frac{(0\text{mEq/L} + 0\text{mEq/L}) - 170\text{mEq/L}}{35\text{L}+1}\right] = 4.72 \text{ mEq/L}$$

170mEq/L- 4.72mEq/L = about **165 mEq/**L

If solutions other than 5% Dextrose in water are used, the table below shows the Na content for common hypotonic solutions

Solution	mEq/L Na
5% Dextrose in water	**0**
0.2% Sodium chloride in 5% dextrose water	**34**
0.45% Sodium chloride in water	**77**
Ringers lactate	**130**
0.9% Sodium chloride in water	**154**

Correcting plasma Na+

- Recommended rate of correction is 1 mEq/ hr

- and no more than 10-12 mEq/24Hrs

Predicting plasma Na+ during correction of water deficit

The pNa+ after 12hr of the 1L infusion will therefore be: 170 –4.72 = 165.2 mEq/L. Knowing the expected change in PNa+ one can determine the amount of hypotonic fluid to be given from the start.

If the goal is to lower the PNa+ by 10mEq/L over 24hrs in our example the volume of solution is 10/4.72 = 2.1L

Predicting plasma Na+ during correction of water deficit

How is this useful?

Hypotonic fluids usually available to correct hypernatremia or water deficit include: pure water given orally or by nasogastric tube, intravenous 5 % dextrose and 0.45 percent NaCl with or without dextrose.

The choice of solution and rate of administration depends on the clinical situation. It is generally recommended not to lower plasma Na+ rapidly to avoid cerebral symptoms; generally, a rate of 10 to 12 mEq over 24 hr is considered safe for chronic hypernatremia.

If the hypernatremia has developed acutely the rate of correction of plasma Na+ can be faster than with chronic hypernatremia.

Osmolar Gap Calculation

- 45 Yo male with alcoholism found unresponsive by the police and brought to the ER Labs as follows

BUN 30, Glucose 100, Plasma Na+ 140, K 4, Cl 108, HCO3 10meq/L,

- What is the plasma osmolality?
- Calculated OSM = ***$2Na^{+}$ + BUN/2.8 + Glucose/18***
- In this case the calculated osmolality was 296 mosm/Kg H2O
- Osmolar Gap = Measured – calculated osmolality
- Measured Osmolality was 360 mosm/Kg H2O
- Osmolar Gap = 64 (normal about 12)

- More info: EtoH level was 80 mg/dl
- What was the cause of the Osmolar Gap?
- Ethanol (mg/dl) can be included in the formula
- ***Calculated=2Na+BUN/2.8+Glucose 18+Ethanol/4.6***
- Calculated osmolality now is 313 (normal about 298)
- And the osmolar gap is now 360-313= 47
- What is the cause of the osmolar gap now?

- Serum ethanol levels are as follows:
- Negative: no alcohol detected
- Lower limit of detection [2] = 10 mg/dL
- >80 mg/dL (>17.4 mmol/L) is considered positive for driving under the influence in most states
- >300-400 mg/dL (65.1-86.8 mmol/L) potentially fatal

Causes of High Osmolar Gap (OG)

SITUATION	pH	AG	KETO	GLU	OG
Ethanol only	N	N	N	N	HI
Methanol (late)	LO	HI	N	N or HI	N or HI**
Isopropanol	N	N	POS	N	HI
Ethylene Glycol	LO	HI	N	N	HI
Alcoholic Ketoacidosis	LO	HI	Weak POS	300	HI
Diabetic Ketoacidosis	LO	HI	POS	300	N or HI (usually < 20-25)

A case of Hyponatremia

- A 72 yr old man weighing 65kg was admitted for acute trochanteric fracture with PNa 140 mEq/L.
- On the 6th post operative day the patient was lethargic with no focal neurological signs, BP 170/93, skin moist, no edema.
- PNa was 119 mEq/L, K 4.0 mEq/L, Cl 89 mEq/L, HCO3 24 mEq/L, BUN 7mg%, Uric acid 2.0mg/dl,
- Uosm 640 mOSm/L, Posm 246.6 Glucose 110 mg/dl, UNa 86 mEq/L, UK 31 mEq/L, Urine Volume=0.3 L/24hr

- What is the calculated free water clearance?
- What is his electrolyte free water electrolyte clearance ?
- What is Urine/Plasma Electrolyte Ratio ?

Free Water Clearance (FWC)

- V= COsm + FWC
- FWC=V-Cosm
- FWC= V- (V x UOsm/POsm) = V (1-UOsm/POsm)

- FWC = (1-UOsm/Posm) V

- PNa was 119 mEq/L, K 4.0 mEq/L, Cl 89 mEq/L, HCO3 24 mEq/L, BUN 7mg%, Uric acid 2.0mg/dl,
- Uosm 640 mOSm/L, Posm 246, Glucose 110 mg/dl, UNa 86 mEq/L, UK 31 mEq/L, Urine Volume=0.3 L/24hr

- Calculate FWC

FWC= (1-640/246)x 0.3/24hr

FWC= -0.48L/24hr or
-478.5ml/24hr

Utility and caveats

- FWC reflects free water excretion or lack of.
- A negative value implies free water retention as the cause of hyponatremia. Whereas, a positive value implies free water excretion as the cause of hyponatremia
- However, longitudinal changes need to be monitored. For instance going from -0.48L/24hr to -0.1L/24hr is an improvement even though the values are still negative

Electrolyte free water clearance

- EFWC= (1-UNa+UK/PNa)V

- For the same patient now calculate EFWC

- PNa was 119 mEq/L, K 4.0 mEq/L, Cl 89 mEq/L, HCO3 24 mEq/L, BUN 7mg%, Uric acid 2.0mg/dl,
- Uosm 640 mOSm/L, Posm 246, Glucose 110 mg/dl, UNa 86 mEq/L, UK 31 mEq/L, Urine Volume=0.3 L/24hr

- EFWC = (1-86+31/119) 0.3/24hrs

- EFWC = 0.21ml/hr or
  5ml/24hr

Patient is given Tolvaptan under recommendation of Nephrology

- Urine osmolality and electrolytes are measured at the same time as plasma osmolality and electrolytes TWO hours later as follows:
- PNa= 121 mEq/L
- Posm= 258 mOsm/L
- Urine Osm= 200 mOsm/L
- Urine Na = 20
- Urine K= 25
- Urine Volume = 200 ml/24hr

Calculate the current FWC

- FWC= 0.2 (1-200/258)/1hr
- FWC= 44mL/hr or
  1079 ml/24hr

Calculate the current EFWC

EFWC = 0.2(1-20+25/121)/1hr

EFWC = 125ml/hr or
3014ml/24hr

Before Tolvaptan

- PNa= 119 mEq/L
- Posm= 246
- Urine Osm= 640
- Urine Na = 86
- Urine K= 20
- Urine Volume= 12ml/ hr
- FWC = -20ml/hr
- EFWC = 0.21ml/hr

After Tolvaptan (2hrs)

- PNa=121 mEq/L
- Posm= 258 mOsm/L
- Urine Osm= 200 mOsm/L
- Urine Na = 20
- Urine K= 25
- Urine Volume = 200 ml/ hour
- FWC = 44ml/hr
- EFWC = 125ml/hr

U/P electrolyte ratio

- Urine/Plasma electrolyte ratio

  $= (UNa^{+} + UK^{+})/PNa$

In our patient, now calculate the U/P electrolyte ratio

PNa was 119 mEq/L, K 4.0 mEq/L, Cl 89 mEq/L, HCO3 24 mEq/L, BUN 7mg%, Uric acid 2.0mg/dl, Uosm 640 mOSm/L, Posm 246, Glucose 110 mg/dl, UNa 86 mEq/L, UK 31 mEq/L, Urine Volume=0.3 L/24hr

U/P electrolyte ratio = (86+31)/119

- U/P electrolyte ratio = 0.98
- What does it mean?

Clinical utility

- The ratio is useful when assessing the degree of free water retention usually associated with hyponatremia.
- A ratio <0.5 indicates significant electrolyte free water excretion
- A ratio between 0.5-1.0 indicates some clearance but not sufficient to correct prevailing hyponatremia
- A ratio >1.0 indicates no electrolyte free water is excreted

Degree of fluid restriction based on the ratio as follows:

- >1.0 → complete restriction
- 0.5-1.0 → about 500ml/day
- <0.5 → about 1000ml/day

Correcting Hyponatremia

- 82 year old female with confusion over the last several hours and history of unstable gait noted on the previous days. She was on HCTZ for hypertension and had been told that drinking is good for the kidneys.
- Plasma Na 110, Wt 60 kg and estimated total body water is 40% of total body weight.

- The physician decides to use hypertonic saline using the following formula (see app)
- The goal of the physician in this case was to increase the plasma sodium to 118 meq/l safely.
- He decides that 1 mEq/hr for 8 hrs would be a safe and yet decisive approach.

calculate the infusion rate

- 3% NaCl infusion rate = $\frac{\text{Na required x 1000ml}}{\text{513(mEq) x hours}}$
- Na required = (target PNa – Observed PNa) x TBW
- = (118 – 110) x TBW

- TBW is total body water (estimated by age and gender)

- 513mEq is the total content of sodium in one liter of 3% hypertonic

- Infusion rate :
- 0.8 mL/min, 46 mL/hour, or 1122.8 mL/24hour

What happened to this patient?
Plasma sodium 2 hours post infusion was up to 112 meq/L and 6 hours later was 117 and the physician decided to stop the infusion

good call ?

A case of polyuria

- 50 year old patient with history of bipolar disorder on long term lithium therapy complaints of increased thirst and urination. Evaluation of his labs reveals the following: plasma Li^+ 1.05mmol/L, PNa 140 mEq/L, PK 4.0mEq/L, Posm 295 mOsm/kg, Uosm 228 mOsm/kg, Urine Volume 4.7 L/24hr
- What is the Free Water Clearance ?

Free Water Clearance (FWC)

- V= COsm + FWC
- FWC=V-Cosm
- FWC= V- (V x UOsm/POsm) = V (1-UOsm/POsm)

- FWC = (1-UOsm/Posm) V

FWC = (1-Uosm/Posm) V

- FWC= (1-228/295) 4.7L/24hr
- FWC= 1.06 L/24hr or 1067ml/24hr
- COsm = V-FWC
- COsm= 4.7-1.06= 3.6 L/24hr

- If a person has a urine volume of 1.5L/24hr, UOsm 700 mOsm/L, Posm 290 mOsm/L

- What would be the FWC and Cosm ?

- FWC= 1.5 (1-700/290)/24hr=-2.1L/24hr
- COsm= V- FWC = 1.5-(-2.1) = 3.6 Osm/24hrs

How do you treat the first patient ?

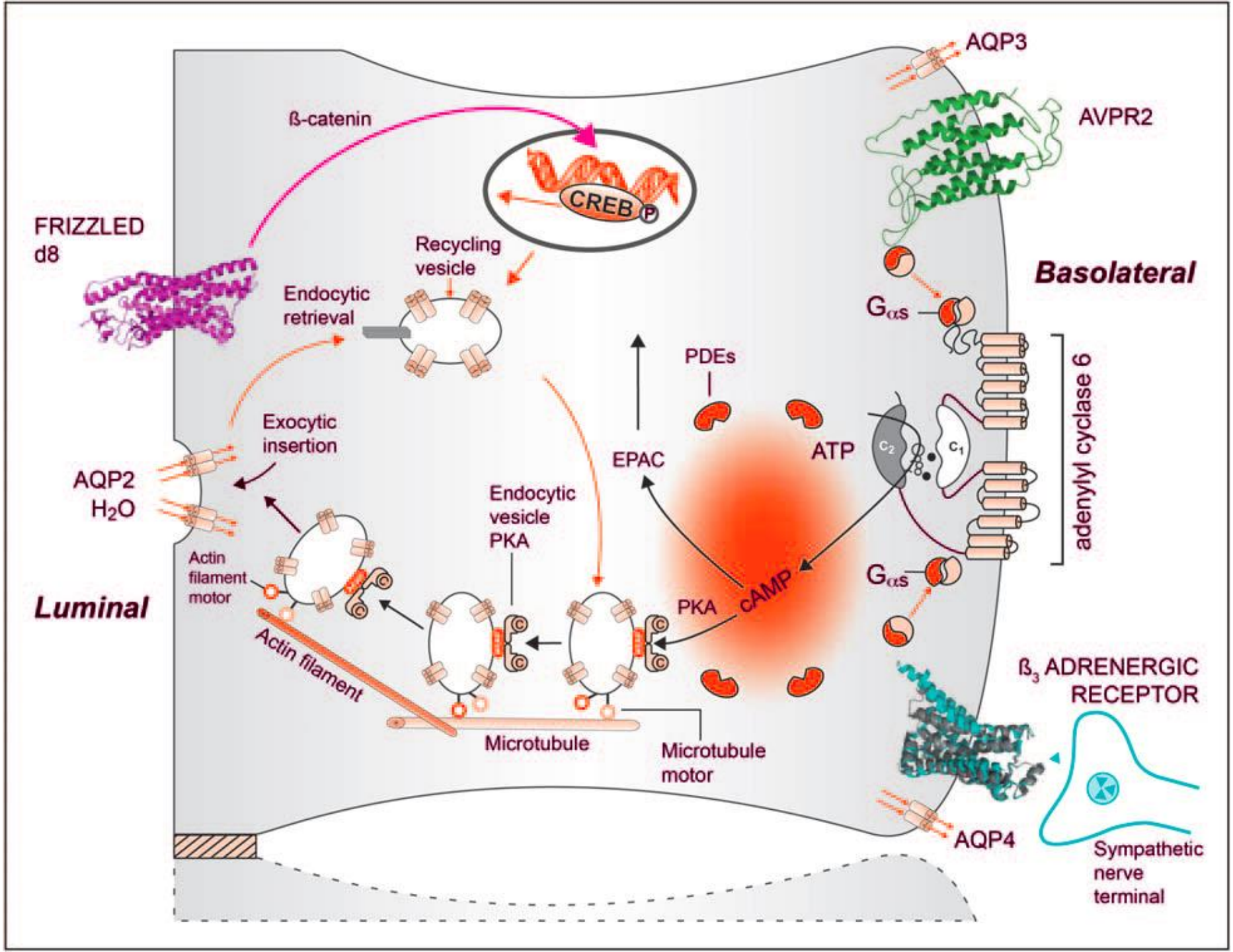
After treating with Amiloride

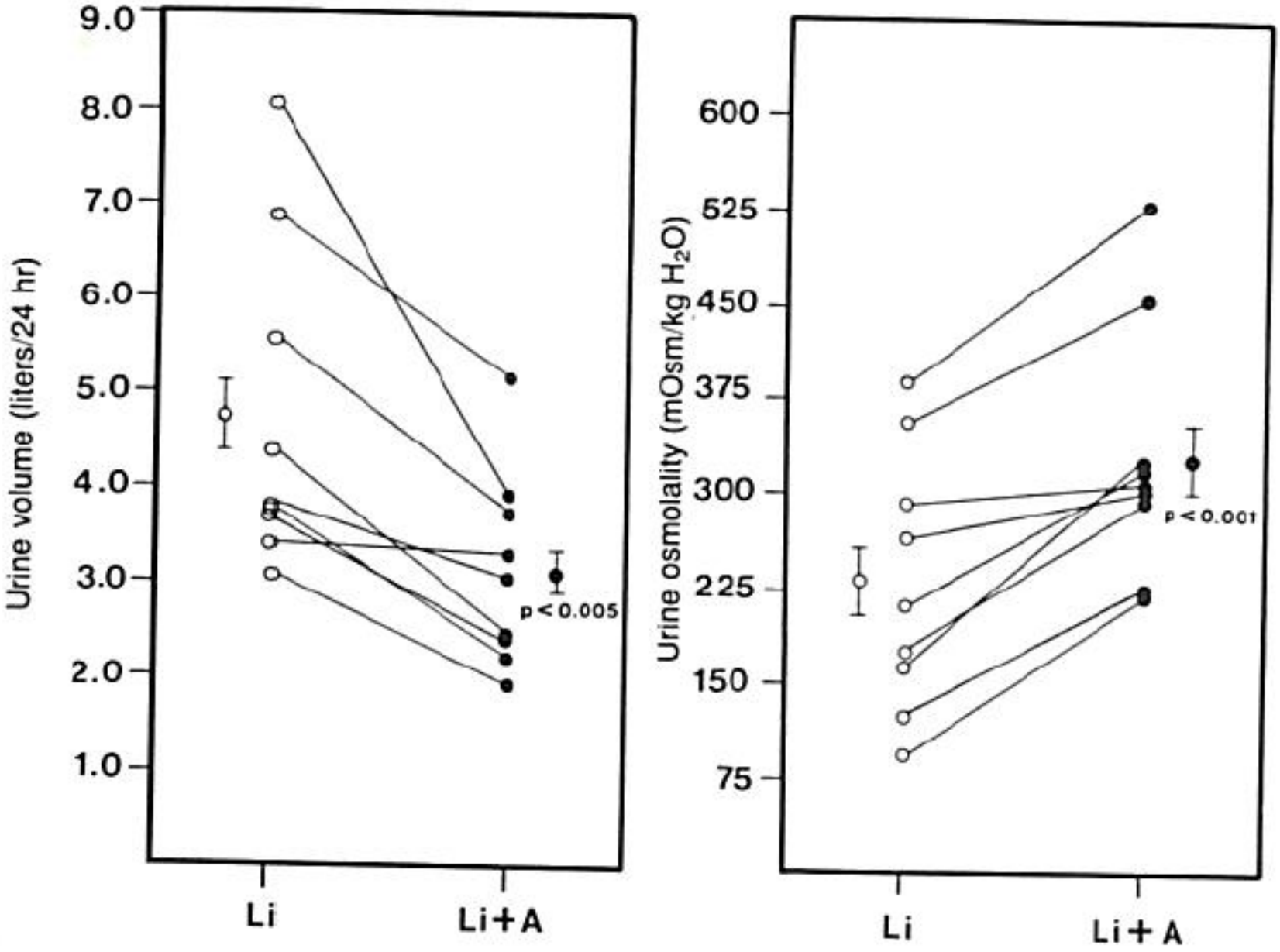
- The labs reveal Plasma Li 0.96mmol/lit, PNa mEq/L, PK 4.4mEq/L, Uosm 331 mOsm/Kg, Posm 290 mOsm/kg, Urine Volume 3.1 L/24hr
- What is the FWC and COsm now?

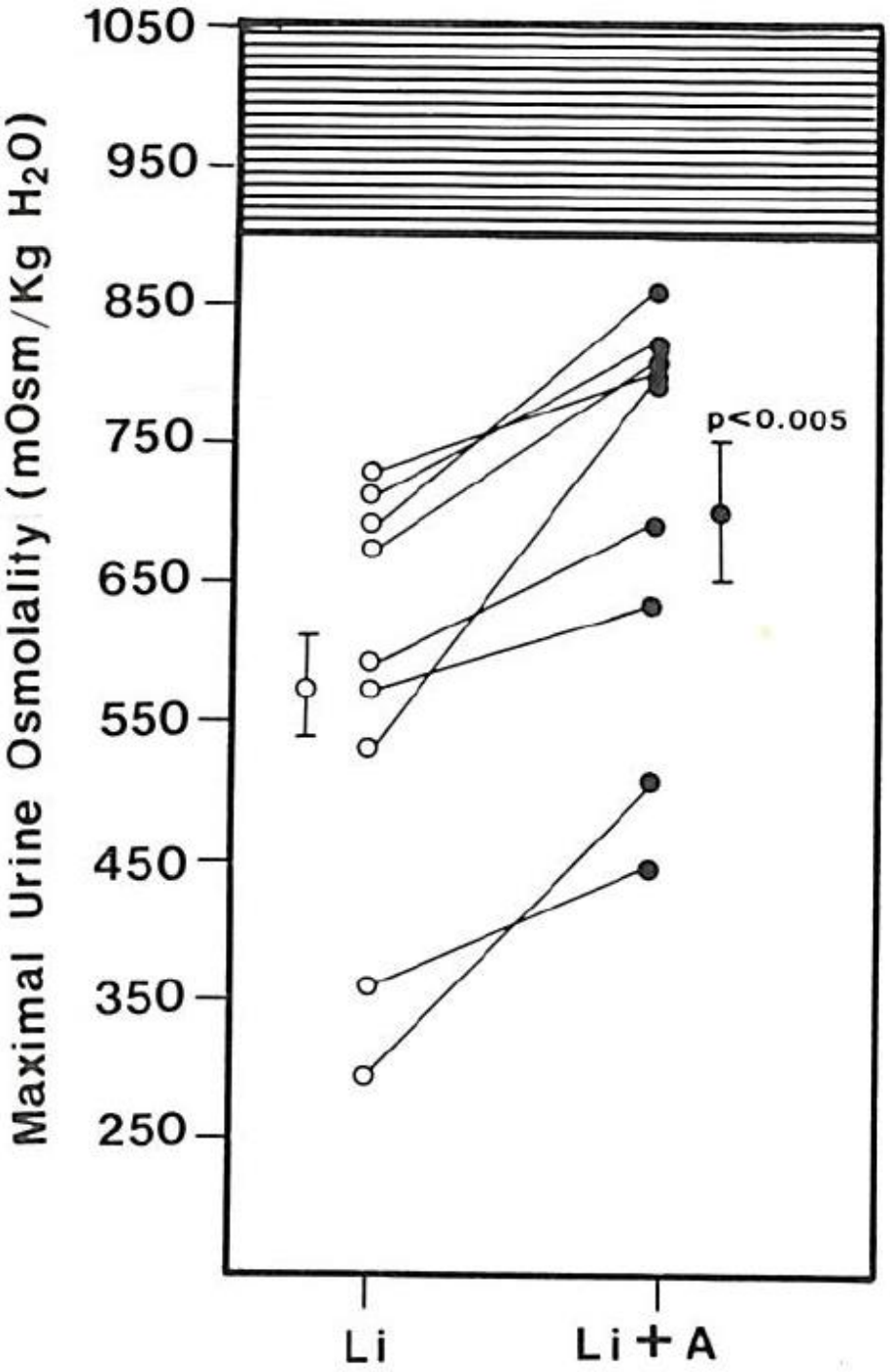
FWC = (1-Uosm/Posm)V

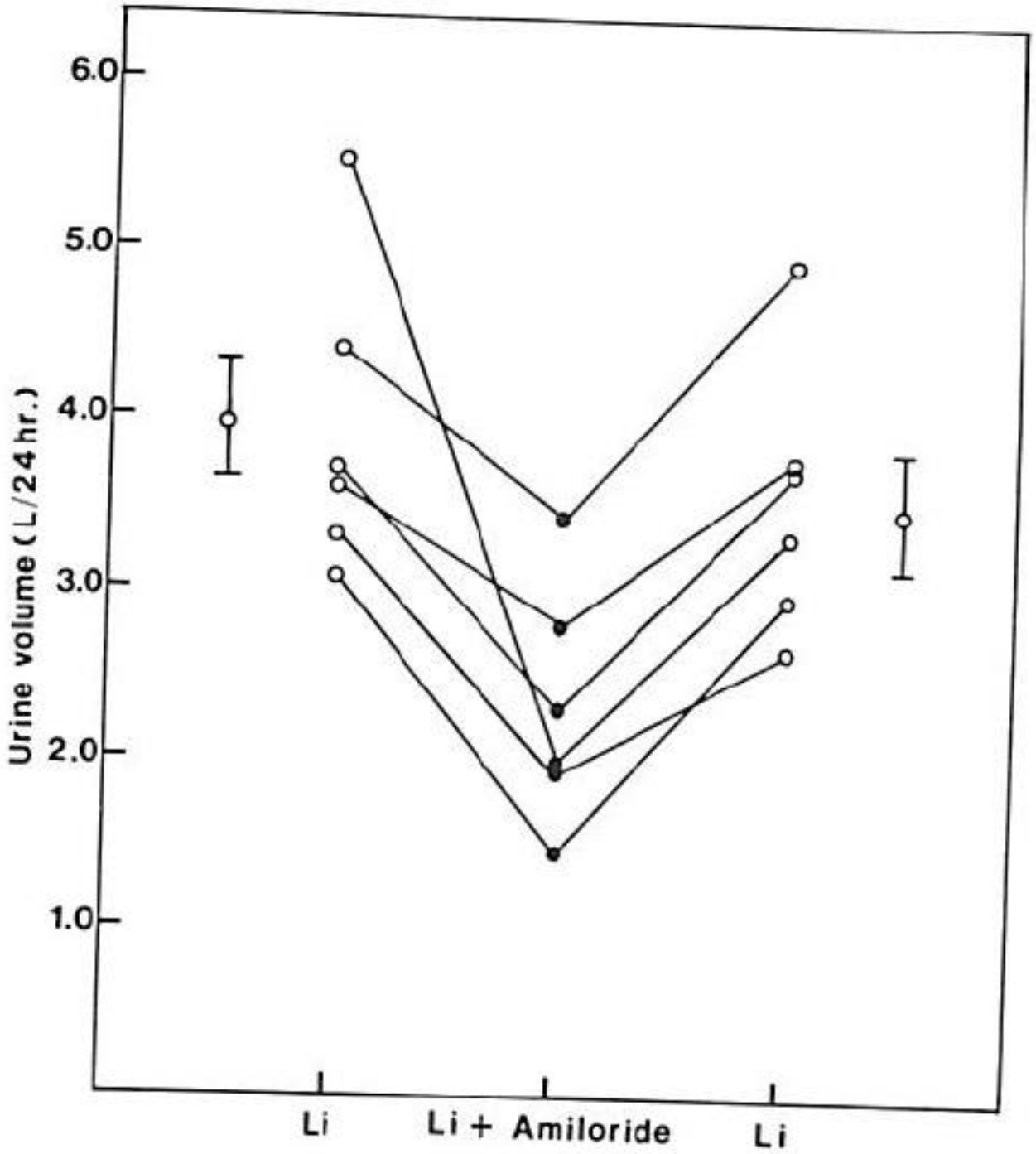
- FWC= 3.1 (1-331/290)/24hr
- FWC= -0.43L/24hr
- COsm = 3.1 – (-0.43) = 3.5 Osm/24hr

Which is close to the earlier value of 3.6 Osm/24hr


AQP3
AVPR2
ß-catenin
CREB
P
FRIZZLED
d8
Recycling
vesicle
Endocytic
retrieval
Basolateral
Gαs
PDEs
Exocytic
insertion
EPAC
ATP
C2
C1
adenylyl cyclase 6
AQP2
H2O
Endocytic
vesicle
PKA
Actin
filament
motor
Luminal
PKA
cAMP
Gαs
Actin filament
ß3 ADRENERGIC
RECEPTOR
Microtubule
Microtubule
motor
AQP4
Sympathetic
nerve
terminal


Urine volume (liters/24 hr)
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
p < 0.005
Li
Li+A
Urine osmolality (mOsm/kg H2O)
600
525
450
375
300
225
150
75
p < 0.001
Li
Li+A


Maximal Urine Osmolality (mOsm/Kg H_2O)
1050
950
850
750
650
550
450
350
250
p<0.005
Li
Li + A


6.0
5.0
4.0
3.0
2.0
1.0
Urine volume (L/24 hr.)
Li
Li + Amiloride
Li