ANSWER KEY
Integrative Sciences: Biological Systems B
Body Fluid/Electrolytes and Kidney Systems

Problem Set Review

Monday, November 28, 2011 at 9 am

Lecturer: Lisa M Harrison-Bernard, PhD

I. Body Fluid Problems - Shifts of water between compartments

What happens to the following 5 parameters:

ECF volume?
ICF volume?
ECF osmolarity?
Plasma protein concentration (PPC)?
Blood pressure?

A. Infusion of isotonic NaCl (isosmotic volume expansion)

B. Diarrhea - loss of isotonic fluid (isosmotic volume contraction)

C. Excessive NaCl intake - addition of NaCl (hyperosmotic volume expansion)

D. Sweating in a desert - loss of water (hyperosmotic volume contraction)

E. Syndrome of inappropriate antidiuretic hormone (SIADH) - gain of water (hypoosmotic volume expansion)

F. Adrenocortical insufficiency - loss of NaCl (hypoosmotic volume contraction)
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<th>ECF Volume (L)</th>
<th>ICF Volume (L)</th>
<th>ECF Osmolarity (mOsm)</th>
<th>PPC (g%)</th>
<th>Blood Pressure (mmHg)</th>
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II. **Starling Forces**

1. At the afferent arteriolar end of a glomerular capillary, $P_{GC}$ is 45 mmHg, $P_{BS}$ is 10 mmHg, and $\pi_{GC}$ is 27 mmHg.

What are the value and direction of the net ultrafiltration pressure?

$$P_{UF} = (P_{GC} - P_{BS}) - (\pi_{GC} - \pi_{BS})$$

$$P_{UF} = (45 - 10 \text{ mmHg}) - (27) = 8 \text{ mmHg}$$

favors filtration of fluid out of the glomerular capillary

III. **Renal Clearance, Renal Blood Flow, Glomerular Filtration Rate**

2. To measure GFR:

Infuse inulin intravenously until $P_{IN}$ is stable. Measure urine volume produced in a known period of time (urine flow). Measure $P_{IN}$ and $U_{IN}$.

Given the following:

$P_{IN} = 0.5 \text{ mg/ml}$

$U_{IN} = 60 \text{ mg/ml}$

Urine flow = 1.0 ml/min

Calculate GFR?

$$GFR = C_{IN} = (U_{IN})(UV) ÷ P_{IN}$$

$$GFR = (60 \text{ mg/ml}) \times (1 \text{ ml/min}) ÷ (0.5 \text{ mg/ml}) = 120 \text{ ml/min}$$

3. To estimate Renal Plasma Flow (RPF):

Infuse PAH. Obtain a timed, complete urine collection and a blood sample. Measure $P_{PAH}$, $U_{PAH}$, and urine flow.

Given the following:

$P_{PAH} = 0.05 \text{ mg/ml}$

$U_{PAH} = 29.5 \text{ mg/ml}$

Urine flow = 1.0 ml/min

Calculate $C_{PAH}$?

$$RPF = C_{PAH} = (U_{PAH})(UV) ÷ P_{PAH}$$

$$C_{PAH} = (29.5 \text{ mg/ml}) \times (1.0 \text{ ml/min}) ÷ (0.05 \text{ mg/ml}) = 590 \text{ ml/min} \sim RPF$$
4. Calculation of Renal Blood Flow (RBF): \[ \text{RBF} = \frac{\text{RPF}}{1 - \text{HCT}} \]

Given the following:
Hematocrit = 0.45
RPF calculated in problem #3

What is RBF = ?

\[ \text{RBF} = \frac{590 \text{ ml/min}}{1 - 0.45} = 1,072 \text{ ml/min} \]

5. Calculation of Filtration Fraction (FF): Fraction (%) of renal plasma flow that is filtered (moves across the glomerular capillary walls into the Bowman's space) as blood traverses the kidney. \[ \text{FF} = \frac{\text{GFR}}{\text{RPF}} \]

Given the GFR and RPF calculated in problems #2 and #3
What is FF = ?

\[ \text{FF} = \frac{120 \text{ ml/min}}{590 \text{ ml/min}} = 0.20 = 20\% \]

6. Fractional Excretion (FEQ) is the fraction (%) of filtered substance (Q) that is excreted in the final urine. \[ \text{FE}_Q = \frac{\text{Amount excreted/min} \div \text{Amount filtered/min}}{\text{U}_Q \text{V} \div (P_Q \times \text{GFR})} = \frac{\text{Clearance}_Q}{\text{GFR}} \]

Given the following:
\[ \text{Clearance}_{Na} = 0.9 \text{ ml plasma/min} \]
GFR from problem #2

What is FE_{Na} = ?

\[ \text{FE}_{Na} = \frac{\text{C}_{Na}}{\text{GFR}} = \frac{(0.9 \text{ ml/min})}{(120 \text{ ml/min})} = 0.0075 = 0.75\% \]

7. Fractional Reabsorption (FR) is the fraction (%) of filtered substance that is reabsorbed by the tubules. \[ \text{FR}_Q = 1 - \text{FE}_Q \]

Given the FE_{Na} calculated in problem #6
What is FR_{Na} = ?

\[ \text{FR}_{Na} = 1 - \text{FE}_{Na} \]
\[ \text{FR}_{Na} = 1 - 0.0075 = 0.9925 = 99.25\% \]
8. Creatinine is a substance that is excreted primarily by filtration and is produced by the body at a fairly constant rate. Thus, it can be used to estimate glomerular filtration rate (GFR).

Given the following data:
24 hour urine volume = 1.2 liters
$U_{Cr} = 144 \text{ mg/100 ml}$
$P_{Cr} = 2 \text{ mg/100 ml}$

8A. Calculate the GFR.

$$GFR = C_{Cr} = (U_{Cr})(UV) ÷ P_{Cr}$$
$$GFR = (144 \text{ mg/100 ml})(1,200 \text{ ml/1,440 min}) ÷ (2.0 \text{ mg/100 ml}) = 60 \text{ ml/min}$$

8B. Is this value below normal, normal, or above normal? 
Below normal

9. In many experimental studies, inulin is used to measure GFR because it is easily measured and only filtered. Also, PAH is used to estimate the plasma flow because the kidney extracts it from plasma very efficiently.

Given the following data:
urine flow = 3 ml/min
$P_{IN} = 0.22 \text{ mg/ml}$
$U_{IN} = 9.5 \text{ mg/ml}$
$P_{PAH} = 0.08 \text{ mg/ml}$
$U_{PAH} = 20 \text{ mg/ml}$

9A. Calculate the GFR and PAH clearances.

$$GFR = C_{IN} = (U_{IN})(UV) ÷ P_{IN}$$
$$GFR = (9.5 \text{ mg/ml})(3 \text{ ml/min}) ÷ (0.22 \text{ mg/ml}) = 130 \text{ ml/min}$$

$$RPF = C_{PAH} = (U_{PAH})(UV) ÷ P_{PAH}$$
$$C_{PAH} = (20 \text{ mg/ml})(3.0 \text{ ml/min}) ÷ (0.08 \text{ mg/ml}) = 750 \text{ ml/min} \sim RPF$$

9B. Calculate the filtration fraction.

$$FF = \frac{GFR}{RPF} = \frac{130 \text{ ml/min}}{750 \text{ ml/min}} = 0.17 = 17\%$$

9C. If the hematocrit is 0.40, what is the total renal blood flow?

$$RBF = RPF ÷ (1–HCT)$$
$$RBF = 750 \text{ ml/min} ÷ (1–0.4) = 750 \text{ ml/min} ÷ 0.6 = 1,250 \text{ ml/min}$$