BioE 110 Midterm 2 Solutions

(1)
(A)
IRV $= VC - ERV - V_T$
$= 5L - 1.2\ L - 0.5\ L$
$= 3.3L$

(B)
alveolar ventilation rate $= (V_T - V_D)*BR$
VD $= V_T*(P_{aCO2} - P_{Eco2})/P_{aco2}$
$= (0.5L)*(38mmHg - 30\ mmHg)/(38\ mmHg) = 0.105L$
$= (0.5L - 0.105L)*10 = 3.95\ L/min = 3949\ ml/min$

(C)
$P_{AO2} = P_{IO2} - (P_{ACO2}/R)$
$R=0.8$
$P_{IO2}=(P_{TOT} - P_{H2O})*X_{O2}$
$=142.6\ mmHg$
$P_{AO2} = 142.6mmHg - 38mmHg/0.8$
$P_{AO2} = 95.1\ mmHg$

(D) Asthma causes constriction of airways in lung, resulting in an increase in resistance. Therefore FEV_1 would decrease.

(E) COPD results in an increase in elasticity in the lung. Therefore the pressure needed to prevent collapse of the lungs in greater. The pursed lips increase intramural pressure and prevent collapse.

(2)
(a)
P=2T/R
$=(2*30mN/m/50x10^{-6}m)*(1N/1000mN) = 1200\ N/m^2$
(b)
Better ventilation results in an increase in V. Also increased pressure restricts blood flow and causes a decreased Q. Therefore the V/Q ratio is increased.
(c)
Patient likely developed a pneumothorax; the increased pressure punctured lung tissue and caused dissipation of negative pressure in pleural space. This resulted in collapse of the lung.
(d)
The patient likely developed a clot in the leg (deep venous thrombosis) and that clot resulted in the swelling. The patient also likely developed a Pulmonay embolism causing the short breath and pain in the chest. The blood thinners reduced both and improved the condition. [Note: a dislodged clot in the leg will travel to the lungs.]

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3. (20 pts) Consider a healthy 21-year old female with the following arterial blood gas values:

$P_{aO2} = 100$ mmHg
$P_{ACO2} = 45$ mmHg

A. If this young woman is breathing room air at atmospheric pressure and BTPS conditions and her ratio of CO_2 eliminated to O_2 consumed (R) is 0.8 (see question 1), estimate her alveolar-arterial (A-a) gradient. (10 pts)

B. Suppose that 6 months later, she develops a severe case of viral pneumonia that leads to bilateral pulmonary edema. How would you expect her A-a gradient to change? Justify your answer using terms in the A-a gradient equation (5 pts).

C. Suppose that as a consequence of her pneumonia, she develops acidemia (reduced blood pH). Sketch her hemoglobin oxygenation curve (% hemoglobin saturated by O_2 vs p_{O2}) <u>before</u> and <u>after</u> onset of the acidemia. (5 pts)

A. A-a grad $= P_{AO_2} - P_{aO_2}$ +3

$= \left(P_{IO_2} - \frac{P_{ACO_2}}{R}\right) - P_{aO_2} = \left(143\text{ mmHg} - \frac{45\text{ mmHg}}{0.8}\right) - 100\text{ mmHg}$

+4 using correct numbers (or 150)

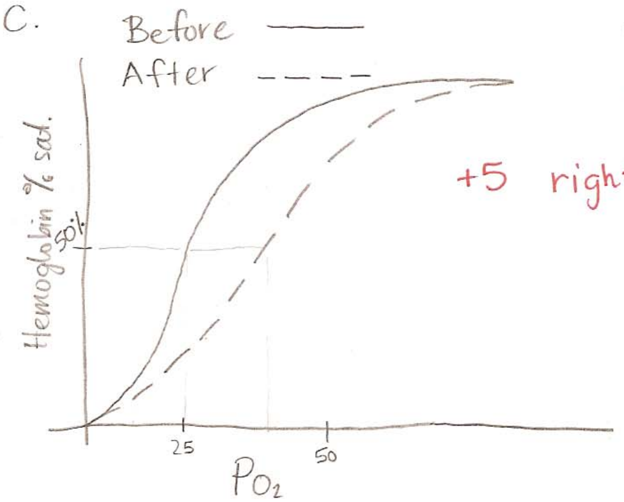
$P_{IO_2} \cong 0.2(760 - 47\text{ mmHg}) = 143$ mmHg
+3

A-a grad = −13.25 or −6.52

Means $P_{aO_2} > P_{AO_2}$

B. If she gets bilateral pulmonary edema, her lungs would have an increased dead space making it harder to exchange gas at the alveoli. In this case $P_{AO_2} > P_{aO_2}$ (+3), so the A-a grad would increase (+2), as would be expected w/ a $\dot{V}/Q$ mismatch.

C.



When pH ↓, there is a decreased affinity for O_2.

+5 right shift

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4. (35 pts) Consider a patient who receives an IV infusion of inulin and para-aminohippuric acid (PAH), and then 24 hours later is subject to urine and blood collection. Suppose those tests reveal the following values:

Urinalysis
Urine output over 24-hour period: 1500 ml → 1 mL/min
Urine concentration of PAH: 75 mg/dL
Urine concentration of inulin: 400 mg/dL
Urine concentration of K+: 45 mEq/L
Urine concentration of Na+: 25 mEq/L
Urine osmolarity: 800 mEq/L

Blood work
Plasma concentration of inulin: 10 mg/dL
Plasma concentration of PAH: 0.5 mg/dL
Plasma concentration of K+: 4.0 mEq/L
Plasma concentration of Na+: 140 mEq/L
Plasma concentration of BUN: 17 mg/dL
Plasma concentration of Glucose: 90 mg/dL
Hematocrit: 0.45

A. Calculate the clearance ratio of Na+. How would you expect this value to change in someone who begins to take furosemide (lasix) and why? (1-2 sentences) (10 pts)

B. Determine the filtered load of Na+ (in mEq/hr), the rate of elimination of Na+ through the urine (mEq/hr), and the % of Na+ that is reabsorbed. (10 pts)

C. Calculate the osmolarity of this patient's blood (mOsm/L) and determine the clearance of free water (mL/min). (10 pts)

D. If this patient later developed a tumor that secreted renin, how would you expect his plasma Na+ concentration to change and why? (1-2 sentences) (5 pts)

A. $\frac{C_{Na}}{C_{inulin}}$

$$C_{Na} = \frac{[U]_{Na} \times \dot{V}}{[P]_{Na}} = \frac{25\ mEq/L \times 1\ mL/min}{140\ mEq/L} = \boxed{0.178\ \frac{mL}{min}}$$ +2

$$C_{inulin} = \frac{[U]_{in} \times \dot{V}}{[P]_{in}} = \frac{400\ mg/dL \times 1\ mL/min}{10\ mg/dL} = \boxed{40\ mL/min}$$ +2

$$\boxed{\frac{C_{Na}}{C_{in}} = \frac{0.178\ mL/min}{40\ mL/min} = 0.00445}$$ +1

+5 If the person began to take Lasix, it would stop the Na/Cl/K exchanger, reducing the amount of Na reabsorption. So C_{Na} would increase +2, thus the clearance ratio would increase. +3

B. Filtered Load = GFR × $[P]_{Na}$ = $C_{in} \times [P]_{Na}$

$$= 40 \frac{mL}{min} \times 140 \frac{mEq}{L} \times \frac{1L}{1000mL} \times \frac{60\ min}{1\ hr} = \boxed{336 \frac{mEq}{hr}}$$ +4

Excretion Rate = $\dot{V} \times [U]_{Na}$

$$= 62.5 \frac{mL}{hr} \times 25 \frac{mEq}{L} \times \frac{1\ L}{1000\ mL} = \boxed{1.56 \frac{mEq}{hr}}$$ +4

$$\frac{1.56}{336} = 0.46\%\ \text{excreted} \Rightarrow \boxed{99.54\%\ \text{reabsorbed}}$$ +2

C. $C_{H2O} = \dot{V} - C_{osm}$

$$= \dot{V} - \frac{[U]_{osm} \times \dot{V}}{[P]_{osm}}$$

what is $[P]_{osm}$?

$$\boxed{[P]_{osm} = 2 \times [P]_{Na} + [P]_{Glu} + [P]_{BUN}}$$ +3

$$= 2 \times 140 \frac{mEq}{L} + \frac{90}{18} \frac{mEq}{L} + \frac{17}{2.8} \frac{mEq}{L}$$

$$\boxed{[P]_{osm} = 291.07 \frac{mEq}{L}}$$ +2

+5

$$C_{H2O} = 1 \frac{mL}{min} - \frac{800 \frac{mEq}{L} \times \frac{1L}{1000mL} \times 1 \frac{mL}{min}}{291 \frac{mEq}{L} \times \frac{1L}{1000\ mL}} = 1 \frac{mL}{min} - 2.75 \frac{mL}{min} = \boxed{-1.75 \frac{mL}{min} = C_{H2O}}$$

Probably dehydrated.

D. Renin → breaks down Angiotensinogen → angiotensin I → II
The net result would be an increased amount of angiotensin II in the blood which stimulates Na^+ reabsorption in the proximal tubule. Thus, the $[P]_{Na}$ would increase.
+2 +3

total: 35 pts.

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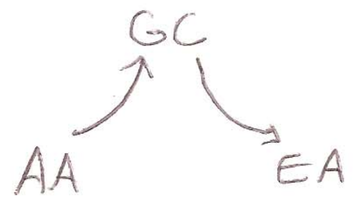
5. (20 pts.) Consider the problem of filtration of solutes in the renal corpuscle (glomerular capillaries and Bowman's space).

A. Suppose you are working at a pharmaceutical company and develop a drug that selectively constricts efferent arterioles while dilating afferent arterioles. How would this drug be expected to affect the glomerular filtration rate (GFR) and why? (5 pts)

B. If the plasma concentration of creatinine is 1.0 mg/dl, the urinary concentration of creatinine is 150 mg/dl, and the urinary output is 1 L/day (0.7 ml/min), calculate the GFR in ml/min. (5 pts)

C. If the renal plasma flow is 500 ml/min and the hematocrit is 0.45, calculate the filtration fraction and renal blood flow in ml/min (10 pts).

A.



$\downarrow$ GFR

$\uparrow P_{GC}$ in $GFR = K_f[(P_{GC} - P_{BS}) - \pi_{GC}]$

B. $GFR \sim C_{creatine} = \frac{[U]}{[P]} \dot{V} = \frac{150}{1}(0.7) = 105$ mL/min

(within ~10%)

C. $RBF = \frac{RPF}{1-Hct} = \frac{500}{1-.45} = 909$ mL/min

$FF = \frac{GFR}{RPF} = \frac{105}{500} = 0.21$

(0.19 w/ 10% GFR correction)

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6. Consider potassium and water balance (20 pts).

A. Consider a 15 year old boy with type I diabetes who requires daily injections of insulin. One day, he accidentally injects himself twice instead of once. Thinking about his plasma insulin levels, what would you expect to happen to his serum potassium and why? (5 pts)

B. Which of these three diuretics is least likely to cause hypokalemia and why: hydrochlorothiazide (HCTZ), furosemide (Lasix), or spironolactone? (5 pts)

C. Consider an otherwise healthy patient who presents with acute dehydration after running a marathon. Would you expect her urine osmolarity to be higher or lower than before she ran the marathon, and why? (5 pts)

D. Would you expect the free water clearance of the woman in C to be positive, negative, or zero after running the marathon, and why? (5 pts)

A. Insulin → ↑ K^+ uptake into cells ⇒ K^+ serum ↓
via upregulation of Na^+/K^+ pump

B. Spironolactone (K^+ sparing)

C. Higher (↑ ADH) b/c of osmoreceptors
thus H_2O permeability ↑ in nephron

D. Negative (corresponding to high ADH, & hyperosmotic urine)
(conserving water)

$$\dot{V} - C_{osm} = \dot{V} - \frac{[U]_{osm}}{[P]_{osm}}\dot{V} < 0$$

$$[U]_{osm} > [P]_{osm}$$