ANSWER KEY TO "NOTES" on RSPT 2350 - Module G - $PaCO_2$ and Alveolar Ventilation

1. **Problems**

A. Given a fixed alveolar ventilation of 4 L/min, calculate the $PaCO_2$ when the CO_2 production is 300 mL/min.

$$PaCO_2 = \frac{\dot{V}CO_2 \times .863}{\dot{V}_A} = \frac{300\,mL/min \times .863}{4\,L/min} = \frac{258.9}{4} = 64.725\ mm\ Hg = 65\ mm\ Hg$$

B. Given a fixed alveolar ventilation of 4 L/min, calculate the $PaCO_2$ when the CO_2 production is 400 mL/min.

$$PaCO_2 = \frac{\dot{V}CO_2 \times .863}{\dot{V}_A} = \frac{400\,mL/min \times .863}{4\,L/min} = \frac{345.2}{4} = 86.3\ mm\ Hg = 86\ mm\ Hg$$

For each of the following conditions, state if the $PaCO_2$ – $PETCO_2$ difference should be normal/near normal or widened.

I. A 64 year old female with pulmonary edema **NORMAL**

II. A 35 year old women with normal lungs who is hyperventilating **NORMAL**

III. A 24 year old man with right lower lobe pneumonia **NORMAL**

IV. A 42 year old woman with pulmonary embolism **INCREASED**

V. A 78 year old man with hypovolemic shock **INCREASED**

VI. A 30 year old man with normal lungs, exercising on a treadmill at 5 mph for 10 min **NORMAL**

C. Given a V_t of 400 mL, physiologic V_d of 200 mL and a f of 16/min, calculate the alveolar minute ventilation ($\dot{V}_A$).

$$\dot{V}_A = (V_t - V_d) \times f = (0.4L - 0.2L) \times 16 = .2 \times 16 = 3.2\,L/min$$

D. Given a $\dot{V}_E$ of 10 L/min, and a $\dot{V}_D$ of 4 L/min, calculate the $\dot{V}_A$.

$$\dot{V}_A = \dot{V}_E - \dot{V}_D = 10\,L/min - 4\,L/min = 6\,L/min$$

E. Given a $\dot{V}_E$ of 12 L/min, f of 20/min, and a physiologic V_d of 120 mL, calculate the alveolar minute ventilation ($\dot{V}_A$)

$$\dot{V}_A = \dot{V}_E - \dot{V}_D = \dot{V}_E - (V_d \times f) = 12\,L/min - (120\,mL \times 12) = 12\,L/min - 2.4\,L/min = 9.6\,L/min$$

Case Study

An intern is called to the hospital bedside of an elderly woman late at night. The patient was admitted to the hospital 3 days earlier for a problem unrelated to her heart or lungs. She is anxious and complains of shortness of breath. Her lung fields are clear to auscultation and

vital signs are normal except for slight tachycardia and a respiratory rate of 30/min. A nurse comments that the patient "gets like this every night." The physician orders an anti-anxiety drug for what he describes as hyperventilation and anxiety. About 30 minutes later, the patient's breathing slows considerably and she becomes cyanotic whereby she is intubated and transferred to the intensive care unit. What would you guess this patient's blood gas values were before she received the anti-anxiety drug?

$PaCO_2$ = 32 mm Hg, PaO_2 70 mm Hg
$PaCO_2$ = 43 mm Hg, PaO_2 80 mm Hg
F. $PaCO_2$ = 58 mm Hg, PaO_2 62 mm Hg
Discussion: The intern mistakenly suspected that the patient was hyperventilating without reference to an ABG. He assumed she was hyperventilating because she was breathing fast. In reality, the patient was hypoventilating and hypoxemic. She had undiagnosed COPD and chronic hypercapnia. By giving an anti-anxiety agent, she decreased her alveolar ventilation, which resulted in a rise in $PaCO_2$ and a decrease in PaO_2. Narcotics, sedatives/anti-anxiety agents should be given with caution to any spontaneously breathing patient with airway disease (COPD) or neuromuscular disease COPD since these drugs can depress respiration.

Example 1

A patient with respiratory acidosis on mechanical ventilatory support is 6'2" and weighs 190 lbs. The Exhaled V_t is 400 mL, and the f is 10/min. The patient is on controlled volume ventilation. The $PaCO_2$ is 60 mm Hg, pH 7.33. The patient's desired $PaCO_2$ is 40 mm Hg. What ventilator change must be made to decrease the $PaCO_2$? The doctor asks you to increase the V_t to correct the $PaCO_2$ to 40 mm Hg.

Actual $PaCO_2$ x Actual V_t = Desired $PaCO_2$ x Desired Vt
60 mm Hg x 400 mL = 40 mm Hg x (?)
2400ml*mm Hg=40 mm Hg x (?)
$$\frac{\mathbf{2400}}{\mathbf{40}}\boldsymbol{mL} = \mathbf{600}\,\boldsymbol{mL} = \boldsymbol{Desired\ V_t}$$

Example 2

A woman who is 5'2" is on controlled ventilation. She has a $PaCO_2$ of 58 mm Hg; pH is 7.28, V_t 625 mL, and a f of 7/min. Plateau pressure is measured as 30 cm H_2O. How can a desired $PaCO_2$ of 40 mm Hg be achieved? (IBW is 52 kg)

Actual $PaCO_2$ x Actual f = Desired $PaCO_2$ x Desired f
58 mm Hg x 7/min = 40 mm Hg x (?)
406 mmHg * breaths/min =40 mm Hg x (?)
$$\frac{\mathbf{406}}{\mathbf{40}} = \mathbf{10}\,\boldsymbol{breaths/min}$$

Example 3

A patient has a pH of 7.66, $PaCO_2$ 20 mm Hg, HCO_3^- 22 mEq/L, PaO_2 89 mm Hg on FIO_2 of 40% is being ventilated in the control mode with no spontaneous breaths and a V_t of 700 mL, f of 18/min. The doctor asks you to correct the pH and $PaCO_2$.

Actual $PaCO_2$ x Actual f = Desired $PaCO_2$ x Desired f
20 mm Hg x 18/min = 40 mm Hg x (?)
360 mmHg * breaths/min =40 mm Hg x (?)

$$\frac{360}{40} = 9 \textit{ breaths/min}$$

Example 4

You are ventilating a patient on the Servo ventilator. The $\dot{V}_E$ is set at 7 L/min and f at 12/min on A/C volume ventilation. The pH 7.29, $PaCO_2$ 60 mm Hg, HCO_3^- is 28 mEq/L, the PaO_2 89 mmHg and the FIO_2 .40. Which ventilator change would you make to restore the $PaCO_2$ to normal?

Actual $PaCO_2$ x Actual $\dot{V}_E$ = Desired $PaCO_2$ x Desired $\dot{V}_E$
60 mm Hg x 7 L/min= 40 mm Hg x (?)
420 mm Hg* L/min = 40 mm Hg x (?)

$$\frac{420}{40} = 10.5 \textit{ L/min is Desired } \dot{V}_E$$

Example 5

You are ventilating a patient in A/C mode with a V_t of 600 mL, f 12/min, FIO_2 50%, Peak flowrate 60 L/min. The $PaCO_2$ is 60 mm Hg, HCO_3^- 35, pH 7.39, PaO_2 88 mm Hg. What ventilator change would you recommend?

Increase the V_t to 800 mL
Increase the f to 16/min
Decrease the f to 8/min
Increase the FIO_2 to 60%
Maintain current settings

Example 6

You are ventilating an 18-year old male patient with a closed head injury from an automobile accident. The ph is 7.53, $PaCO_2$ 25 mm Hg, HCO_3^- 20 mEq/L, PaO_2 100 mm Hg. You notice that the patient is receiving IV mannitol. The V_t is 700 mL, f 16/min, FIO_2 40% on A/C volume ventilation. The nurse asks your recommendation for ventilator changes. What changes would you recommend?

Increase the V_t to 800 mL
Decrease the V_t to 500 mL
Decrease the f to 12/min
maintain current settings **DECEPTIVE QUESTION – NEED ICP MEASUREMENT**
Decrease the FIO_2 to 30%

Example 7

You are ventilating a burn patient in ICU on A/C Volume Ventilation. The V_t is 1.0 Liters, f 10/min, $PaCO_2$ is 40 mm Hg, pH 7.40, PaO_2 89 mm Hg, HCO_3^- 24 mEq/L. The patient's spontaneous V_t is 800 mL and f is 15/min. The patients total $\dot{V}_E$ is 22 L/min. How would you interpret the patient's condition? List clinical situations in which CO2 production may be increased?

INCREASED CO_2 PRODUCTION SECONDARY TO BURN

IT IS ALSO INCREASED WITH SEPSIS, FEVER, OVERFEEDING (ESPECIALLY WITH CARBOHYDRATES), EXERCISE, AND EXCESSIVE BICARBONATE ADMINISTRATION (HCO_3^- CONVERTS BACK TO CO_2)

Example 8

You are ventilating a patient on the Servo ventilator with a minute ventilation of 8 L/min. The pH is 7.23, $PaCO_2$ 66 mm Hg, HCO_3^- 32 mEq/L, PaO_2 68 mm Hg. The doctor asks you to correct the pH. What is the desired level of $PaCO_2$?

To get to a pH level in the normal range you need an HCO_3^-: $PaCO_2$ (in mEq/L) ratio of 20:1. The current ratio is 32:(66*.03) or 32:1.98 or 16.2:1 ratio. To return to a normal pH (using only the $PaCO_2$, i.e. no change in HCO_{3-}) we need to solve the following ratio:

32 :(Desired $PaCO_2$ * .03) = 20:1
32/(Desired $PaCO_2$ * .03) = 20/1
20 * (Desired $PaCO_2$ * .03) = 32 * 1
(Desired $PaCO_2$ * .03) = 32/20
(Desired $PaCO_2$ * .03) = 1.6
Desired $PaCO_2$ = 1.6/.03 = 53.3 mm Hg

How would you change the ventilator settings to correct to the new $PaCO_2$ level?

Actual $PaCO_2$ x Actual $\dot{V}_E$ = Desired $PaCO_2$ x Desired $\dot{V}_E$
66 mm Hg x 8 L/min= 53 mm Hg x Desired $\dot{V}_E$
528 mm Hg * L/min = 53 mm Hg x Desired $\dot{V}_E$
$\frac{528}{53} = 10\ L/min$ **is Desired** $\dot{V}_E$

Example 9

You are ventilating a patient on the servo with a minute ventilation of 12 L/min, $PaCO_2$ 24, HCO_3^- 18, pH 7.50. How would you change the ventilator (change only the $PaCO_2$) to restore a normal pH? The first step is to determine the level of $PaCO_2$ desired?

Current ratio is 18/(24*.03) or 18/.72 or 25:1 ratio.

18:(Desired $PaCO_2$ * .03) = 20:1
18/(Desired $PaCO_2$ * .03) = 20/1
20 * (Desired $PaCO_2$ * .03) = 18 * 1
(Desired $PaCO_2$ * .03) = 18/20
(Desired $PaCO_2$ * .03) = 0.9
Desired $PaCO_2$ = 0.9/.03 = 30 mm Hg

How would you change the ventilator settings to correct to the new $PaCO_2$ level?

Actual $PaCO_2$ x Actual $\dot{V}_E$ = Desired $PaCO_2$ x Desired $\dot{V}_E$

24 mm Hg x 12 L/min = 30 mm Hg x Desired $\dot{V}_E$

288 mm Hg * L/min = 30 mm Hg x Desired $\dot{V}_E$

$$\frac{288}{30} = 9.6\ L/min \text{ is Desired } \dot{V}_E$$