MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Departments of Electrical Engineering, Mechanical Engineering, and the Harvard-MIT Division of Health Sciences and Technology

6.022J/2.792J/BEH.371J/HST.542J: Quantitative Physiology: Organ Transport Systems

QUIZ 3

Thursday, April 29, 2004

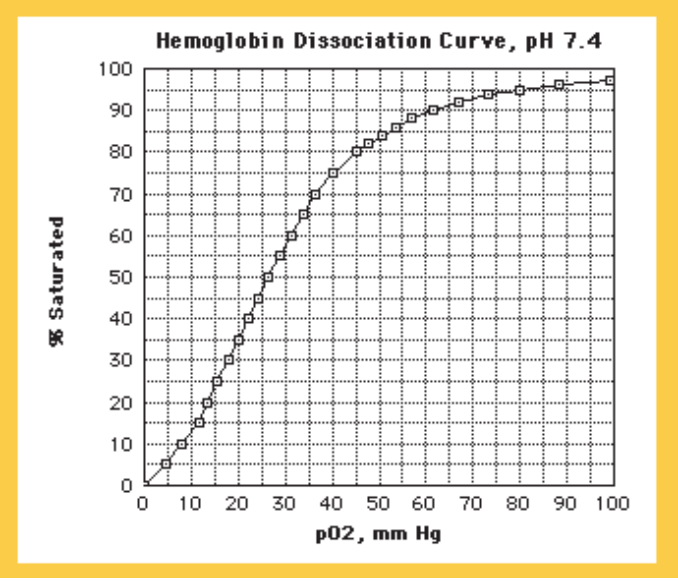
Name: _____

These are normal values of physiological parameters for a 70 kg person.

R_{rs} (respiratory system R)	=	4	mbar·s/l
C_{cw}	=	200	ml/mbar
C_{lung}	=	200	ml/mbar
V_D (Anatomic)	=	150	ml
V'_{O_2}	=	274	ml/min
V'_{CO_2}	=	220	ml/min
RQ	=	0.8	
Q_s/Q_T (Shunt fraction)	<	0.05	
Q_T (cardiac output)	=	5	l/min
P_{atm}	=	760	mmHg
$P_{v_{CO_2}}$	=	46	mmHg
$P_{v_{O_2}}$	=	40	mmHg
$P_{a_{CO_2}}$	=	40	mmHg
$P_{a_{O_2}}$ (at room air)	=	100	mmHg
$(A-a)DO2$	≈	6-10	mmHg
pH	=	7.4	
cHb	=	15	g/100ml-blood
Hb O_2 Binding capacity	=	20.1	ml O_2/100ml blood
FRC	=	2.4	l

The normal hemoglobin O_2 saturation curve is also included and should be used only when there is no alternative data available.

Figure 1:



The first two problems are cases that include certain respiratory physiologic abnormalities. You can use the normal values as a reference, or in absence of additional information.

Problem 1 (Case 1)

A patient comes to the emergency ward with shortness of breath and wheezing. He is breathing room air at a rate of 30 breaths per minute, and the pulse oximeter shows his arterial blood saturation to be $S_{a_{O_2}} = 0.80$.

Arterial and mixed venous blood samples are taken at arrival and reveal the following values:

$P_{v_{CO_2}}$	=	44	mmHg
$P_{v_{O_2}}$	=	27	mmHg
$P_{a_{CO_2}}$	=	39	mmHg
$P_{a_{O_2}}$ (at room air)	=	20	mmHg

The blood gas data comes with a computer generated caution questioning the validity of the measurements.

A. Please identify which of the four blood gas values may have an error and explain your reasoning. (25%)

B. You need to make a best guess to treat the patient with the knowledge available to you; can you find an approximate value of the erroneous blood gas? (25%)

C. The patient is given 100% O_2 by mask and one hour later his blood gases come back:

$P_{v_{CO_2}}$	=	48	mmHg
$P_{v_{O_2}}$	=	47	mmHg
$P_{a_{CO_2}}$	=	42	mmHg
$P_{a_{O_2}}$	=	60	mmHg

This time without caution notes.

What can you say about the cause of gas exchange impairment in this patient? (50%) Hint, you can ignore the oxygen carrying capacity of plasma in your calculations.

Problem 2 (Case 2)

The same patient eventually develops respiratory failure and is placed on a mechanical ventilator adjusted to parameters matching his tidal breathing:

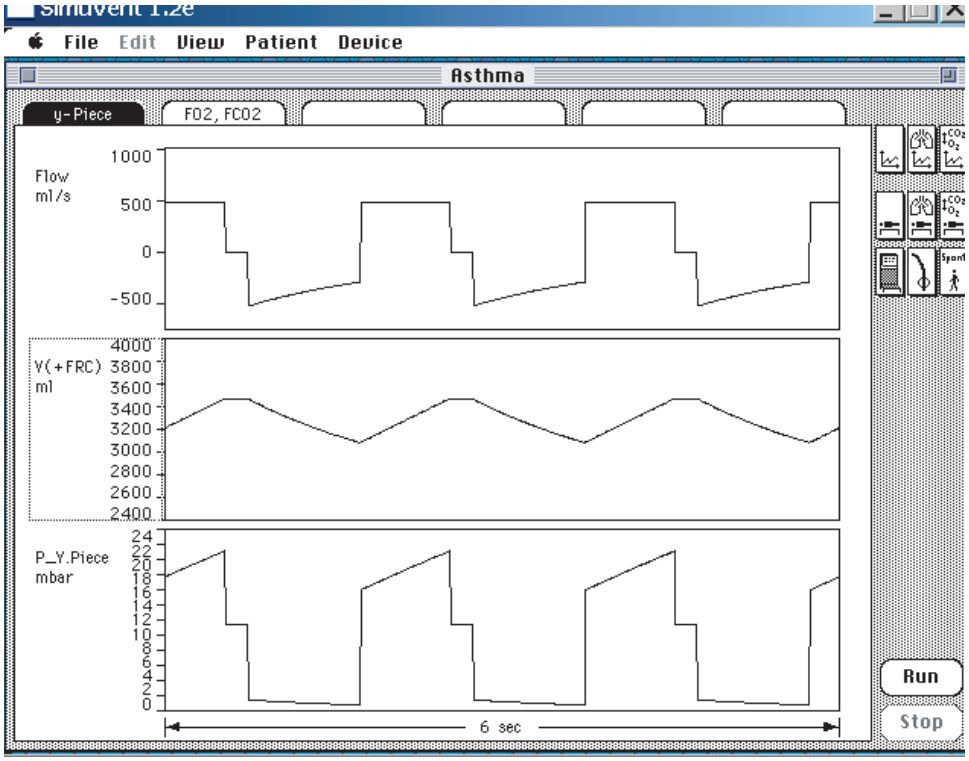
$$VT = 390 \text{ ml} \qquad f = 30 \text{ bpm} \qquad T_{ins} = 40\% \qquad T_{exp} = 50\% \qquad F_{iO_2} = 0.50$$

And his blood gases are measured as:

$$\begin{aligned} P_{v_{CO_2}} &= 42 \text{ mmHg} \\ P_{v_{O_2}} &= 45 \text{ mmHg} \\ P_{a_{CO_2}} &= 40 \text{ mmHg} \\ P_{a_{O_2}} &= 275 \text{ mmHg} \\ \\ \dot{V}_{O_2} &= 274 \text{ ml/min} \\ \dot{V}_{CO_2} &= 220 \text{ ml/min} \end{aligned}$$

The ventilator output shows the following screen

Figure 2:



A. Is this patient exhibiting dynamic hyper-inflation, and why or why not? (25%)

B. Can you estimate the patient's respiratory system mechanical parameters: Resistance and Compliance? (25%)

C. The attending MD suggests decreasing frequency while keeping the inspiration (insufflation in Germanic English) and exhalation time % unchanged. What frequency and tidal volume would you choose? Assume that the VD physiologic remains unchanged. (50%)

(Note: if you decide to use VD anatomic in your calculation, you will lose 25% of the question points.)

Problem 3

Pulmonary fibrosis is a debilitating disease of the lung characterized by replacement of elastin by collagen and resulting in a decrease of lung compliance. In severe cases, lung transplant is the only option for survival. To maximize organ availability and reduce post-operative mortality, usually unilateral lung transplant is conducted.

A. First draw the normal chest wall and lung compliance curves. Then draw changes that result from pulmonary fibrosis (C_L reduced by 1/2). Assume that compliances are linear and that the chest wall compliance does not change. What happens with FRC in pulmonary fibrosis? (25%)

B. Second, draw the effects of replacing one of the lungs with a normal donor lung. What will be the new FRC after surgery? You can assume that both right and left lungs have equal compliance before surgery. (25%)

C. How does the amount of pressure required to inspire a similar tidal volume compare between before and after surgery? (25%)

D. In what proportions is the tidal volume distributed between both lungs? (25%)