HUMAN SIMULATION: HAEMORRHAGE (HYPOVOLEMIA) STUDENT NOTES

Method

We will start by making some baseline observations of cardiovascular variables when the simulated subject is in a normal, healthy resting state.

We will then simulate the effects on the cardiovascular system of a scenario involving loss of increasing amounts of blood volume, followed by returning the volume to close to normal values.

We will then explore the responses to an increase in blood volume above normal levels.

You will then analyse these data, producing graphs that explore the properties of the whole-body response to hypovolemia with a focus on understanding the action of the baroreceptor reflex.

Equations

There are several equations you will need to be familiar with to understand and analyse the data obtained from the simulation:

1. Heart rate (bpm) = 60 / R-R interval (s)

2. Mean arterial pressure (mmHg) = cardiac output (l/min) x total peripheral resistance (mmHg/l/min)

3. Mean arterial pressure (mmHg) = diastolic pressure (mmHg) + 1/3 pulse pressure (mmHg)

4. Pulse pressure (mmHg) = systolic pressure (mmHg) - diastolic pressure (mmHg)

5. Cardiac output (l/min) = heart rate (bpm) x stroke volume (l)

6. Volume of blood removed as a percentage of total blood volume:
   Simulated male body weight = 90 kg, simulated female = 70 kg,
   and blood volume for most humans is ~70 ml/kg

7. Note that TPR cannot be measured directly, so is calculated from the relationship of
   MAP = CO x TPR.

8. Shock Index = heart rate (bpm) / systolic pressure (mmHg)

Results tables

Table 1, Observations from simulation vs student

Use this table to enter parameters from the simulation and measurements taken on yourself or a colleague

	Human Simulation Data	**Student**
Resting heart rate (beats per minute)		
Resting breathing rate (breaths per minute)		

Table 2, Waveform display for baseline patient

1. Use the table below to sketch the traces recorded on the waveform display
2. Fill in the appropriate values in the boxes on the right-hand side of the table
3. Use the ECG data to draw an approximate time scale bar beneath the ECG waveforms (see equation (i)

Lead II		HR ______ **bpm**
ABP		ABP ______ ***mmHg***

PAP			P A P ______ ***mmHg***
CVP			C V P _____ ***mmHg***
	Thermodilution CO ______ **L/min**		

Background to the traces displayed in the table - *fill in the blanks*

HR Heart rate

ABP Arterial blood pressure (systolic pressure/diastolic pressure) recorded from a catheter inserted into a ___________________________

PAP Pulmonary arterial pressure (systolic pressure/diastolic pressure) recorded from a catheter inserted via the venous system, through the ________________ side of the heart, into the pulmonary artery

CVP Central venous pressure recorded from a catheter inserted into the venous system until its tip is situated at the junction of the ____________________________ and the ______________________________. Note that the waveform oscillates over time – the oscillations result from changes in interpleural (intrathoracic) pressure throughout the __________________________ cycle. CVP also changes with the cardiac cycle resulting in the A, C and V waves, these waves were not discernible from the simulated CVP recording.

CO Cardiac output - determined by a method that involves rapid injection of cold saline into the right atrium (or ventricle) and using a thermistor to record the "downstream" changes in temperature in blood flowing through the pulmonary artery or via doppler ultrasound

Shock stages

Use to complete Table 3

Parameter	I	II	III	IV
Blood loss (ml)	<750	750-1500	1500-2000	>2000
Blood loss (%)	<15	15-30	30-40	>40
Heart rate (bpm)	<100	>100	>120	>140
Blood pressure	Normal	orthostatic	hypotension	Severe hypotension
CNS symptoms	Normal	Anxious	Confused	Unconscious

Table 3, Response to hypovolemia through blood loss and fluid replacement

The simulated patient will **lose 600 ml of blood, deteriorating to a loss of 3 litres**. Fluids will then be administered reducing the overall deficit to **2.1 and 1.2 litres.** The simulated male body weight is **90 kg,** simulated female is 70 kg, and blood volume is usually **70 ml/kg**. At the end of the scenario the blood volume will be returned to baseline and then a **further 2000 ml** of fluid added (i.e. hypervolemic)

*Fill in the following table from the results that are obtained each time blood is removed from the 'subject'. * These values will need to be derived during or after the simulation session. The '0' column refers to no fluid deficit or blood loss, so the 'normal' subject.*

Fluid volume deficit (ml)	0	600	3000	2100	1200	hypervolemic
* Fluid deficit (% of total blood volume)						
*Stage of shock						
Heart rate (beats/min)						
Systolic pressure (mmHg)						
Diastolic pressure (mmHg)						
* Pulse pressure (mmHg)						
* Mean arterial pressure (mmHg)						
*Change in MAP %						
Central venous pressure (mmHg)						
Cardiac output (l/min)						
*Change in C.O. %						
* Stroke volume (ml)						
* Total peripheral resistance (mmHg/l/min)						
*Change in TPR %						
Breathing rate (breaths/min)						
*Shock Index						

<u>Data Analysis</u>

For the purposes of analysis, consider the volume deficit as volumes of circulating blood removed becoming progressively larger, i.e. 600 ml. 1.2 litres, 2.1 litres and finally 3 litres. You do not require the hypervolemic data for the analysis.

1. Graphical analysis

Plot the following graphs as instructed below (omit the hypervolemic data). ***You will need to order the data correctly as explained above to plot the graphs as progressive volume reduction (0, 600, 1200, 2100, 3000 ml deficit, or as a percentage as instructed).***

Graph 1. The relationship between the percentage of circulating blood volume removed and the systolic and diastolic arterial blood pressures (mm Hg) and heart rate (beats/min). Use two vertical axes – one for blood pressure, the other for heart rate. Start both vertical axes from zero.

Graph 2. The relationship between central venous pressure (mm Hg) on the horizontal axis and stroke volume (ml). Sometimes there may be 2 'x' values the same for CVP (e.g. 2 values for CV at 1 mmHg CVP) which can make plotting tricky but this graph only needs to show the overall trend.

Graph 3. The relationship between the percentage of circulating blood volume removed (horizontal axis) and changes in cardiac output, mean arterial pressure and total peripheral resistance (systemic vascular resistance). Express all these values on **the same** vertical axis as **the percentage change** in each variable in relation to its baseline (i.e. pre-bleeding) value.

2. Classes of shock

Fill in the blanks, e.g. 'low', very fast', 'critical'

Class	**Blood loss, %**	**Observation & response**
I	<15	____ blood pressure, _____ heart rate
II	15-30	____ blood pressure, _____ heart rate
III	30-40	____ blood pressure, _____ heart rate
IV	>40	____ blood pressure, _____ heart rate

3. <u>Schematic diagram of the baroreceptor reflex</u>

Using arrows, complete the schematic diagram below to show the relationships between the components of the baroreceptor reflex IN RESPONSE TO A LOSS OF BLOOD (REDUCED MAP). (NB the parasympathetic and endocrine components are omitted.)