HUMAN SIMULATION: HAEMORRHAGE (HYPOVOLEMIA) TEACHER'S NOTES

This scenario is designed for CAE Maestro with Embody with the accompanying SCE.

Use with accompanying slide set.

This scenario examines the common clinical problem of blood loss, however the emphasis is on the underlying control of MAP via the baroreceptor reflex. It is important to explain to students that the aim is not to diagnose and treat an emergency, more so we will be exploring the relationships between reduced venous return, resulting in a reduced MAP, and the autonomic reflex responses that occur to correct MAP, if possible. At 3 litres of blood loss, the patient is quite unwell. However, the scenario will not progress to deterioration unless the instructor wishes this to happen. This is so students may observe the paradoxical decrease in TPR (SVR) during decompensated blood loss. The patient will then recover with fluid infusion.

The scenario is designed to produce profound hypovolemia at the second stage of blood loss, followed by reperfusion which has some degree of realism. Alternatively it may be played out as an experiment using sequential blood loss of 0.6, 1.2, 2.1 & 3 litres. Some learner groups may find this an easier approach and it is more obvious how to plot out the resultant data.

Determination of shock index and stage of shock may not be appropriate for all learner groups.

<u>References</u>

Euliano TY (2001). Small group teaching: clinical correlation with a human patient simulator. Advances in Physiological Education 25, 36-43

**Fujita Y, Yamamoto T, Sano I, Yoshioka N, Hinenoya H (2004).
A comparison of changes in cardiac preload variables during graded hypovolemia and hypervolemia in mechanically ventilated dogs. Anaesthesia & Analgesia 99, 1780-1786**

Lloyd E, Helyer RJ, Dickens PJ, Harris, JR (2006). Human Patient Simulation in physiology teaching: designing a high-fidelity cardiovascular demonstration for first year undergraduates. Proceedings of the Physiological Society 3, PC62

Preisman S, DiSegni E, Vered Z, Perel, A (2002). Left ventricular preload and function during graded haemorrhage and retranfusion in pigs: analysis of arterial pressure waveform and correlation with echocardiography. British Journal of Anaesthesia 88, 716–718

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 **Note all values are indicative and may vary for each simulation**

Table 1, Observations from simulation vs student

The scenario begins with orientation to normal values without blood loss as if we have turned back time.

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)	**66**	
Resting breathing rate (breaths per minute)	**11**	

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)

It should be pointed out to learners that the waveform display shown in the simulation may differ from that of a clinical monitor as we can show parameters that would not be shown in normal monitoring. However this is useful in exploring the autonomic responses. Facilitators may wish to request the arterial catheter is moved to the left ventricle to explore the differences in sys/dias pressures between LV and peripheral artery. It might be explained that CO can be determined by Doppler ultrasound or by thermodilution. Here we are showing values as if determined by thermodilution.

Lead II	**Sketch of typical trace**	HR **66 bpm**

ABP	**Sketch of typical trace**	A B P **123/77** ***mmHg***
PAP	**Sketch of typical trace**	P A P **23/8** ***mmHg***
CVP	**Sketch of typical trace**	C V P **2** ***mmHg***

	CO **5.4** **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 **peripheral artery**.

PAP Pulmonary arterial pressure (systolic pressure/diastolic pressure) recorded from a catheter inserted via the venous system, through the **right** 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 **superior vena cava** and the **right atrium**. Note that the waveform oscillates over time – the oscillations result from changes in interpleural (intrathoracic) pressure throughout the **breathing** 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).

It may be desirable to reorder the stages of hypovolemia into sequence depending on learner group. It should be pointed out that values shown with a * are calculated from the equations provided. It is left to individual instructors as to what signs they may wish to show learners, and whether to show the patient with or without the waveform display at each stage before showing the patient physiological data. Useful signs are pulse (peripheral and carotid, eyelids, pupil reflex, and capillary refill. In order to better show signs, the patient should be presented raised on a bed, and the bed lowered at 3 litres of blood loss. Facilitators may wish to request an oxygen mask (learners may suggest this as a treatment), and an IV drip for application of saline. This is not necessary for the scenario but can add realism if desirable. Learners benefit from seeing the changes occurring with time as volume is removed at each stage, rather than static values presented after the volume has been lost or added back.

Facilitators may wish to add student interaction via polls or other voting in terms of what signs to observe or to predict what physiological responses may occur at each stage of blood loss. It is useful for facilitators to remind students that we are exploring the action of the baroreceptor reflex and to keep in mind the controlled variables and effector arms of the reflex.

A discussion of accuracy of variable measurement vs number of decimal places to express values to may be useful at this point -leaners are likely to express values to an excessive number of decimal points.

Note MAP values calculate may differ to those shown by the waveform display (if selected) due to heart rate change (time spent in diastole varies).

*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)	-	10	48	33	19	n/a
*Stage of shock	-	1	4	3	2	n/a
Heart rate (beats/min)	65	71	131	129	102	48
Systolic pressure (mmHg)	123	118	37	63	98	138
Diastolic pressure (mmHg)	77	78	29	49	73	82
* Pulse pressure (mmHg)	46	40	8	14	25	56
* Mean arterial pressure (mmHg)	94	93	31	54	82	100
*Change in MAP %	0	1	67	43	13	6
Central venous pressure (mmHg)	2	1	-3	-2	-1	21
Cardiac output (l/min)	5.4	5.3	1.6	2.6	4.2	5.3
*Change in C.O. %	0	4	71	53	24	4
* Stroke volume (ml)	83	75	12	20	11	108
* Total peripheral resistance (mmHg/l/min)	17	17.5	19	20.1	20	19
*Change in TPR %	0	3	14	18	15	12
Breathing rate (breaths/min)	11	15	40	33	23	25
*Shock Index	0.5	0.8	3.6	2	1+	n/a

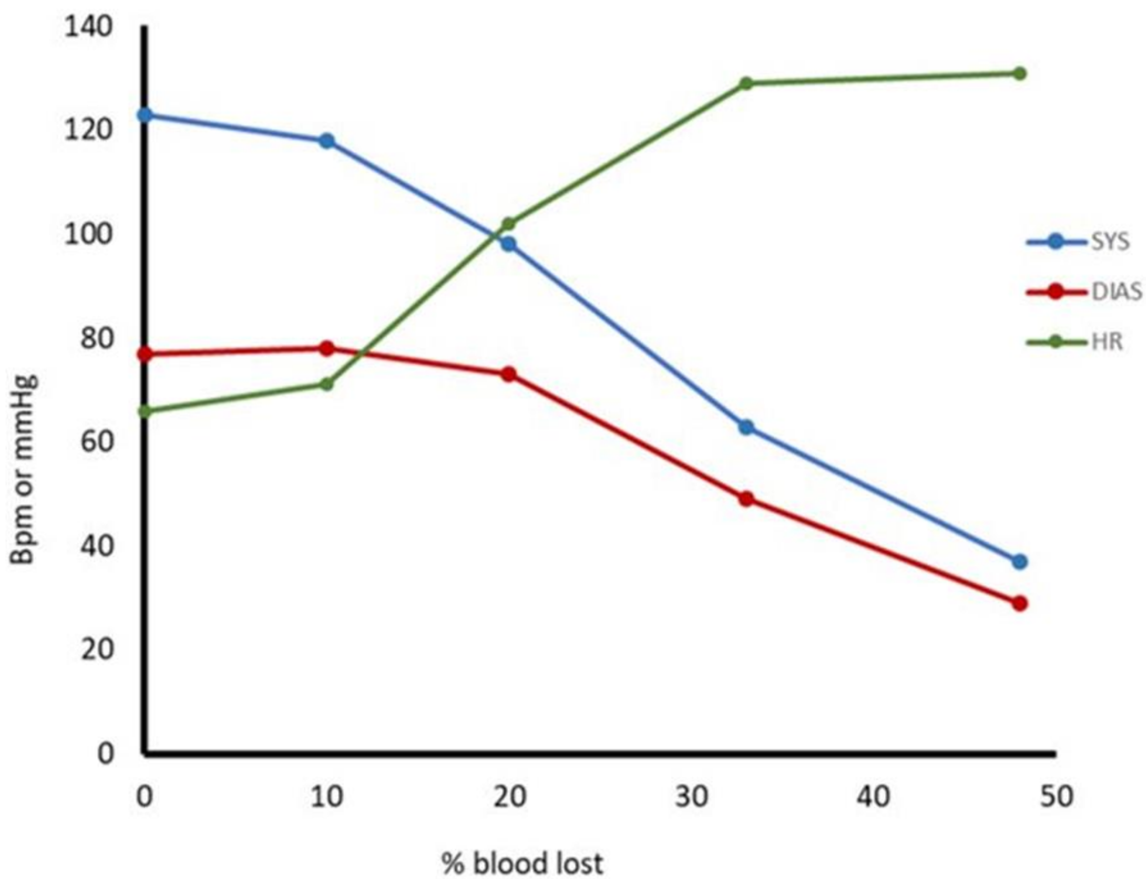
Data Analysis

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.

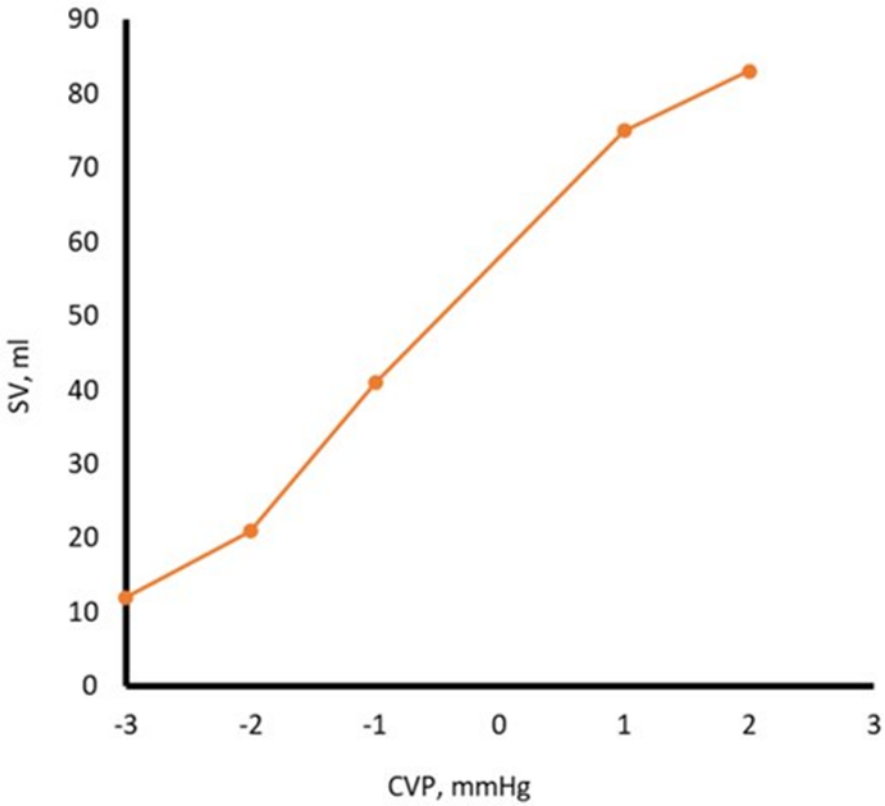
1. Graphical analysis

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).***

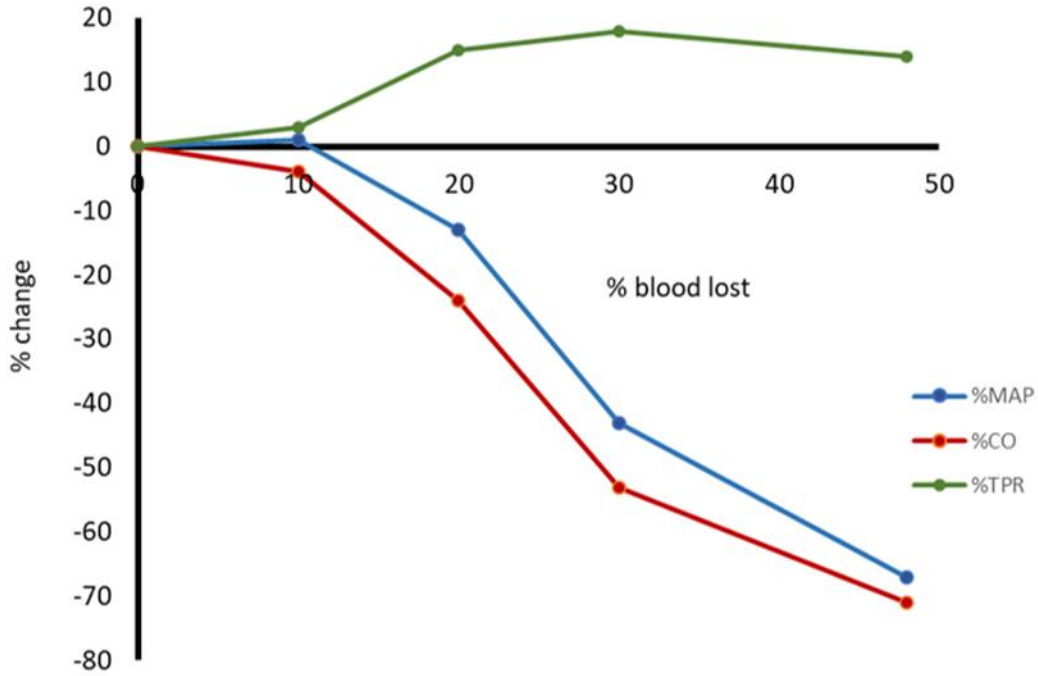
Graph 1. The relationship between the percentage of circulating blood volume removed and the systolic and diastolic arterial blood pressures (mm Hg) and heart rate (beats/min). Use two vertical axes – one for blood pressure, the other for heart rate. Start both vertical axes from zero.



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, **small increase in** heart rate
II	15-30	**decreased** blood pressure, **increased** heart rate
III	30-40	**decreased** blood pressure, **increased** heart rate
IV	>40	**decreased** blood pressure, **increased** heart rate

3. Schematic diagram of the baroreceptor reflex

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.)