Mr. Parks

Load Mr. Parks (MR_PARKS.ICS) using the **File / Load Initial Conditions** main menu selection.

Is Mr. Parks OK? Actually, the thumbnail sketch on the Charts panel suggests that he is not OK.

Check Mr. Parks' blood pressure, heart rate, temperature and respiration using the Monitor panel.

Normal values were taken from Norm Subject.

Variable	**Mr. Parks**	**N. Subject**	**Units**
Blood Pressure		120 / 81	mmHg
Heart Rate		73	Beats / Min
Temperature		98.8	degree F
Respiration Rate		12	Breaths / Min

Estimating Cardiac Output

We'll use some basic hemodynamic concepts in this section to make an estimate of Mr. Park's cardiac output (See G&H, pp. 152 - 156).

Variable	**Symbol**	**Units**
Cardiac Output	CO	mL/Min
Heart Rate	HR	/Min
Stroke Volume	SV	mL
Pulse Pressure	PP	mmHg
Proportionality	K	mL/mmHg

Cardiac output is equal to heart rate multiplied by stroke volume.

$$CO = HR * SV \quad (1)$$

We can observe heart rate at this point but not stroke volume. But, pulse pressure is proportional to stroke volume for each cardiac ejection -- and we can observe pulse pressure. Equation (1) is modified to get

$$CO = HR * K * PP \quad (2)$$

The proportionality constant K is currently unknown. We will take data from Norm Subject to apply to Mr. Parks, hoping that these two have roughly the same arterial compliance.

Symbol	Value	Units
CO	5368	mL/Min
HR	73	/Min
PP	39	mmHg
K	1.9	mL/mmHg

Solving Equation (2) for K using Norm Subject's data yields a value for K of 1.9.

Use this value of K and Mr. Parks hemodynamic data to estimate his cardiac output.

Variable	Value	Units
Pulse Pressure		mmHg
Proportionality	1.9	mL/mmHg
Heart Rate		/Min
Cardiac Output		mL/Min

At this point, what is your preliminary diagnosis? Why?

Use the **View / Basic Physiology** main menu selection to install the basic physiology toolbar buttons.

Select the Blood Flow panel and read Mr. Parks' true stroke volume and cardiac output.

Variable	Value	N. Subject	Units
Stroke Volume		73	mL
Cardiac Output		5368	mL/Min

Select the Blood Volume panel and read Mr. Parks' blood volume.

Variable	Mr. Parks	N. Subject	Units
Blood Volume		5400	mL
Red Cell Volume		2400	mL
Plasma Volume		3000	mL

Hematocrit		44	%

Acute Compensations

Hemorrhage elicits a variety of compensations that help to maintain blood flow to vital organs by supporting blood pressure and redistributing flow toward vital organs (See G&H, Chapter 24). We'll consider two here: increased autonomic nerve activity and increased plasma angiotensin concentration.

Select the Autonomic Efferents panel and read general and kidney autonomic firing rates.

Select the Angiotensin panel and read the plasma angiotensin concentration.

Variable	**Mr. Parks**	**N. Subject**	**Units**
General Autonomic Firing Rate		1.5	Hz
Renal Autonomic Firing Rate		1.5	Hz
Plasma [AII]		20	pG/mL

Time permitting, you might try blocking the increase in autonomic activity and increase in plasma angiotensin to obtain an indication of their effect on arterial pressure.

To block (alpha) autonomic activity, go to Blockers and set alpha receptors % block to 100%. Then go to Monitor to observe the effects of this blockade.

To block the formation of plasma angiotensin conversion, go to Blockers and set AII converting enzyme inhibition to 100%. Again, go to Monitor to observe the effects of this inhibition.

The vasoconstrictor effect of the sympathetic nervous system and angiotensin during hemorrhage is beneficial only if the vasoconstriction is selective. Namely, we hope that brain and heart blood flow (vital organs) is maintained at the expense of flow in other organs, as show below (data from Kaihara).

Select the Blood Flow panel and estimate Mr. Parks' brain and hepatic vein blood flow from the graph. Or, select **View / Organ Details** to make the organ details toolbar buttons visible. Then select the Brain Circulation and Gut panels to get numerical values for blood flow.

Variable	**Mr. Parks**	**N. Subject**	**Units**
Brain Blood Flow		706	mL/Min

Hepatic Vein Blood Flow		1217	mL/Min

Severity Of Hemorrhage

Compensation can almost completely hide the hemodynamic consequences of a mild hemorrhage, such as giving a unit of blood at a blood bank. More severe hemorrhage produces obvious signs even with the strong support of the compensations. With very severe hemorrhage, the compensations are maximum and cannot contribute further; cardiovascular collapse is a real possibility.

It would be instructive to know the severity of Mr. Parks' hemorrhage. Observe Mr. Parks for 10 minutes. Use the main menu **Go** command to advance the solution by 10 minutes.

Interventions

Intervention is advised.

Lost blood volume is usually replaced by one of three types of solutions.

- Saline. It is readily available and safe, but it tends to leak out of the circulation where it is of no or negative value. Saline dilutes the available hemoglobin.

- Saline With Colloid Pressure. Colloid pressure keeps the replacement fluid in the circulation where it boosts cardiac output, but it also dilutes available hemoglobin.

- Whole Or Artificial Blood. Blood is often not readily available (see G&H, Chapter 24). When it is available, it offers colloid pressure to keep the replacement fluid in the circulation and

hemoglobin or a functional equivalent to carry oxygen.

We'll try each of these interventions. Note that the fundamental goal of intervention is to maintain or improve oxygen delivery to the tissues. We'll keep an eye on O2 movement in the simulations that follow.

In each case, begin by clicking **Restart** to take Mr. Parks back to his initial condition. Use the arrow buttons on the toolbar to move among the needed panels.

Saline. Select the IV Drip panel. Set the volume to 1000 mL, the timespan to 10 Min, [NaCl] to 140 mMol and click switch to on. Go back to Monitor, advance the solution for 1 hour and record data in the table below.

Plasma. Select the Transfusion panel. Set the volume to 1000 mL, the timespan to 10 Min, the hematocrit to 0 % and click switch to on. Go back to Monitor, advance the solution for 1 hour and record data in the table below.

Whole Blood. Select the Transfusion panel. Set the volume to 1000 mL, the timespan to 10 Min, the hematocrit to 44 % and click switch to on. Go back to Monitor, advance the solution for 1 hour and record 1-hour data in the table below.

Select the Oxygen panel for blood oxygen data.

Variable	Initial	Saline	Plasma	Blood
Blood Pressure				

Heart Rate				
Blood Volume				
Red Cell Volume				
Plasma Volume				
Hematocrit				
Cardiac Output				
Arterial O_2 Content				
Venous O_2 Content				

Discussion point: What are the good and bad attributes of the three replacement fluids used above, as indicated by the data collected?

Discussion point: What is the volume replacement strategy when a patient intraoperatively bleed more than his/her total blood volume?

The Natural Time Course

The physiological response to hemorrhage is a three-part process, over time. The principal features are:

- Rapidly responding neural and humoral mechanisms direct available blood flow toward

vital organs, as described above.

- More slowly evolving salt and water retention by the kidneys replaces the lost plasma.

- Erythropoiesis gradually replaces the lost red blood cells.

In this section, we'll produce a moderate hemorrhage and observe the body's response over the following month.

Use the **Options / Reset** main menu selection to get Norm Subject back. The thumbnail sketch in Charts should now introduce Norm Subject.

To create a hemorrhage, select the Blood Volume panel. In the arterial hemorrhage box, set volume to 1000 and timespan to 10. Click the hemorrhage switch on and advance the solution 30 minutes.

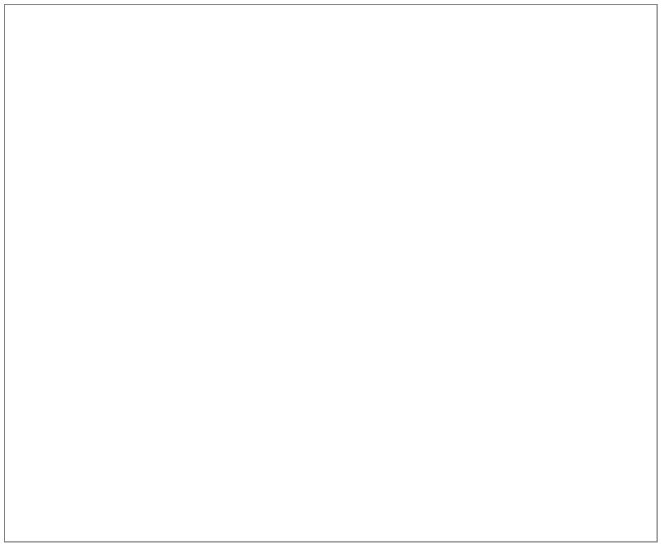
You can verify the neural and hormonal response to hemorrhage, as previously seen above. But, there is also a renal component to be considered.

Use the **View / Nephron Details** main menu selection to add the nephron details button to the toolbar. Select the Urine panel and read the rate of sodium and water excretion.

Variable	30 Min	Control	Units
Sodium Excretion		0.114	mEq/Min

Water Excretion		0.76	mL/Min

Salt and water retention should expand plasma volume and blood volume. But the lost red cells will not be acutely replaced and hematocrit will fall as shown below (data from Ebert, Adamson).



Advance the solution to 2 days and note the amount and composition of blood volume.

Select the Erythropoietin panel to see if EPO secretion has been stimulated.

Select the Blood Volume panel to see if red cell production is increased.

Advance the solution to 30 days, following changes in blood volume and particularly red cell volume. Note the final amount and composition of the blood.

Variable	30 Days	Control	Units
Blood Volume		5400	mL
Red Cell Volume		2400	mL
Plasma Volume		3000	mL
Hematocrit		44	%

References

Adamson, J. and R. S. Hillman. Blood volume and plasma protein replacement following acute blood loss in normal man. *J. Am er. Med. Assn.* 205:609-612, 1968.

Ebert, R. V., E. A. Stead, Jr. and J. G. Gibson, II. Response of normal subjects to acute blood loss. *Arch. Int. Med.* 68:578-590, 1941.

Kaihara, S., R. B. Rutherford, E. P. Schwentker and H. N. Wagner, Jr. Distribution of cardiac output in experimental hemorrhage in dogs. *J. Appl. Physiol.* 27:218-222, 1969.

Mr. Parks - Notes

Mr. Parks' thumbnail sketch notes that he was found in a pool of blood and was rushed to the ER.

Mr. Parks has hemorrhaged and may expire if left untreated.

Creating Mr. Parks

The first step in creating Mr. Parks is to create a large hemorrhage. The new parameter values are:

"Arterial Hemorrhage, Final Volume" = 1800.0

"Arterial Hemorrhage, Duration" = 30.0

"Arterial Hemorrhage, Switch" = 1.0 // On

Then the solution was advanced for 10 minutes and Mr. Parks was constrained to lying down (1.0).

"Posture Control, Restraint" = 1.0 // Lying

Then the solution was advanced for another 20 minutes to complete the hemorrhage.

Finally, a smaller continuing hemorrhage was defined to create a dynamic setting. The new

parameter values are:

“Arterial Hemorrhage, Final Volume” = 500.0

“Arterial Hemorrhage, Duration” = 10.0

“Arterial Hemorrhage, Switch” = 1.0 // On

Mr. Parks is now ready for observation and intervention.

Recap

The immediate physiological response to hemorrhage is neural and humoral vasoconstriction that directs available blood flow toward vital organs. Then, renal salt and water retention expands plasma and blood volume. The slowest part of the response is replacement of lost red cells by increased red cell production.

The effectiveness of volume replacement depends on

- The replacement fluid's tendency to stay in the circulation.
- The replacement fluid's net effect on oxygen delivery to the tissues.

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Mr. Parks Wrap-up

Summary

The immediate physiological response to hemorrhage is neural and humoral vasoconstriction that directs available blood flow toward vital organs. Then, renal salt and water retention expands plasma and blood volume. The slowest part of the response is replacement of lost red cells by increased red cell production.

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