Mr. Stone

Mr. Stone has had severe, continuing diarrhea for about a week. He lost 1 mL/Min with [Na+] of 100 for 4 days.

Mr. Stone is seen in the ER. He only speaks Estonian, so we can't get a history.

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

Is Mr. Stone OK? We don't know, but he is in the ER. Check his blood pressure, heart rate, temperature and respiration using the Monitor panel.

Normal values were taken from Norm Subject.

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

These values seem quite normal, but there are some slight worries. Pulse pressure seems a little narrow and heart rate is a little high. And, respiration rate is up a little bit.

Blood Chemistry

Blood chemistry might be useful. Go to the Blood And Urine Samples panel. Click Take Sample Now in the Venous Blood Sample box. Are the blood electrolytes normal?

Variable	Mr. Stone	N. Subject	Units
[Na+]		145	mEq/L
[K+]		4.4	mEq/L
[Cl-]		108	mEq/L
[BUN]		13	mG/dL
[Protein]		6.9	G/dL
Osmolarity		292	mOsm/L
Hematocrit		44	%

Several values are not quite normal. Plasma [Na+], osmolarity and hematocrit are all elevated a little bit. What does this suggest? We might consider a drip later on.

A bigger worry is the elevated plasma [Cl-]. What does this suggest? We'll investigate further.

Check Mr. Stone's acid/base status. Click Take Sample Now in the Arterial Blood Gases box. Is there evidence of an acid/base disturbance?

Variable	Mr. Stone	N. Subject	Units
pCO2		37	mmHg
pH		7.45	pH Units
[H+]		35	pMol/L
[HCO3-]		26	mEq/L

These values definitely suggest that Mr. Stone has an acid/base disturbance of some sort.

Would you expect the pH in a venous blood sample to be higher or lower than in this arterial sample? Why?

pH Or [H+]?

The definition of pH (see Guyton and Hall, p. 347) is

pH = -log [H+]

when the physical units for [H+] are Mol/L. But [H+] concentrations are usually tiny and nMol/L are more appropriate units. The definition of pH becomes

$$pH = 9 - \log [H+]$$

Here are some commonly encountered values.

[H+]	pH
25	7.60
40	7.40
63	7.20
100	7.00

Calculator buttons ( ) on the Blood And Urine Samples panel can calculate additional values.

The Anion Gap

An analysis of Mr. Stone's anion gap may be useful.

The anion gap (see Guyton and Hall, p. 361-362) is an estimate of anions in a blood sample that are present but not measured in ordinary blood chemistries. The anion gap is calculated as

Anion Gap (mEq/L) = [Na+] - [Cl-] - [HCO3-]

What anions are normally in the anion gap? What ions are in Mr. Stone's anion gap?

Variable	Mr. Stone	N. Subject	Units
[Na+]		145	mEq/L
[Cl-]		108	mEq/L
[HCO3-]		26	mEq/L
Anion Gap		11	mEq/L

This Shoe Didn't Fit

If we encounter a blood sample with a low [HCO3-] concentration (we did) and a normal or decreased [Cl-] concentration (we didn't), there will probably be a large anion gap. Likely candidates to fill this gap are ketoacids (diabetic ketoacidosis) and lactate (anaerobic organ failure). Mr. Stone is not showing us this profile at all, so its time to move along.

Respiratory Function And pH

Respiratory function is always involved in acid/base status.

First, consider the physiological loop that helps to stabilize blood pCO2. This loop operates

as follows: if blood pCO2 increases, pH falls; decreased pH stimulates ventilation; increased ventilation increases exhaled CO2; increased CO2 blow off decreases blood pCO2. Thus, stability.

Now suppose metabolic factors lower pH. Decreased pH stimulates ventilation and increased ventilation increases exhaled CO2, lowering blood pCO2. The decreased blood pCO2 tends to increase pH, buffering the original metabolic event. This is metabolic acidosis with respiratory compensation.

Suppose a respiratory factor, such as pulmonary membrane damage, decreases exhaled CO2. This increases blood pCO2 and lowers pH. This is respiratory acidosis. But decreased pH again stimulates ventilation and this increases exhaled CO2, which tends to buffer the initial insult.

In simplest terms, acidosis with decreased blood pCO2 is probably caused by metabolic factors. Acidosis with increased blood pCO2 is probably caused by respiratory factors.

With this background, we can analyze Mr. Stone's venous blood.

Variable	Mr. Stone	N. Subject	Units

pH		7.45	pH Units
pCO2		37	mmHg

What is your diagnosis at this point?

Mr. Stone's Kidney

It's time to look at Mr. Stone's kidney.

Use the **View / Basic Physiology** and **Nephron Details** main menu selections to install the basic physiology and nephron toolbar buttons.

It might be useful to see what Mr. Stone's kidney is excreting. Go to Urine and record excretion rates for water and important electrolytes.

Variable	Mr. Stone	N. Subject	Units
H2O Rate		0.76	mL/Min
Na+ Rate		0.114	mEq/Min
K+ Rate		0.056	mEq/Min
Cl- Rate		0.125	mEq/Min

HCO3-Rate		0.010	mEq/Min
NH4+ Rate		0.024	mEq/Min

Review G&H Chapter 30 and complete your diagnosis. Focus particularly on the excretion rates for Na+, HCO3- and NH4+.

Body Fluids

We've also had some hints that Mr. Stone may be a little dehydrated. What were those hints? Go to Water and record the volumes of important body fluid compartments.

Variable	Mr. Stone	N. Subject	Units
Total Body H2O		43.2	L
ECFV		15.0	L
Plasma		3.0	L
Interstitium		12.0	L
Cell H2O		28.2	L

Use this information below in prescribing a drip for Mr. Stone.

The proper intervention is to remove the primary cause of the acid/base disturbance, but a drip may temporarily improve Mr. Stone's acid/base status.

Go to IV Drip. Create a plan for infusing sodium bicarbonate. Set the bicarbonate concentration, infusion volume and infusion timespan. Click the drip switch to on. Advance time to complete the drip.

If you don't like the results, click the **Restart** main menu selection and try a different strategy.

Record the final results below and show your instructor.

Variable	Control	Now	Units
[Na+]			mEq/L
[K+]			mEq/L
[Cl-]			mEq/L
[BUN]			mG/dL
[Protein]			G/dL
Osmolarity			mOsm/L

Hematocrit			%
pCO2			mmHg
pH			pH Units
[H+]			pMol/L
[HCO3-]			mEq/L

Show these results to your instructor.

Mr. Stone - Notes

Mr. Stone's thumbnail sketch notes only that he speaks Estonian and so there is no history at the outset.

Mr. Stone has had prolonged diarrhea, producing hyperchloremic metabolic acidosis.

Creating Mr. Stone

Mr. Stone looses 100 mEq of Na+ (along with bicarbonate) a minute and 1 mL of water per minute in his feces. We anticipate not only metabolic acidosis but also dehydration.

The new parameter values are:

"GI Lumen Diarrhea, [Na+] Target" = 100.0

"GI Lumen Diarrhea, H2O Target" = 1.0

Then the solution was advanced for 3 days (3800 minutes).

Mr. Stone is ready.

Recap

Metabolic acidosis presents with decreased blood pH and bicarbonate concentration.

If ketoacids or lactate are the cause of the acidosis, their blood concentrations will be hiding in a widened anion gap. Otherwise the anion gap will be smaller than normal and blood chloride concentration will be increased.

Ventilation has a role in metabolic acidosis. Decreased pH stimulates ventilation which, in turn, blows down blood pCO2. This decrease in pCO2 decreases the severity of the acidosis.

The proper treatment of metabolic acidosis is to remove its primary cause, but sodium bicarbonate administration should provide temporary benefit.

Postscript

An Estonian translator was located. It turns out that Mr. Stone has had a severe, continuing diarrhea for several days. Treatment of lower bowel inflammation is planned.

To see the cause of Mr. Stone's distress, go to  Miscellaneous and scroll to the bottom of the panel.

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Mr. Stone Wrap-up

Summary

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