Ms. Nance

Ms. Nance has chronic heart failure.

Load Ms. Nance (MS\_NANCE.ICS) using the **File / Load Initial Conditions** main menu selection.

Is Ms. Nance OK? Actually, the thumbnail sketch on the  Charts panel suggests there may be problems. Ms. Nance complains that she tires easily and sometimes can't get enough air.

Check Ms. Nance’s blood pressure, heart rate, temperature and respiration using the  Monitor panel.

Normal values were taken from Norm Subject.

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

What values are abnormal and what does this tell you?

Wait And See

First, we will observe Ms. Nance for a day to see if this is a stable condition. Use the **Go** main menu selection to advance the solution for 1 day.

Note that if Ms. Nance should expire, you can request an autopsy report. Use the **View / Autopsy Report** main menu selection to install the autopsy report toolbar button. Then click  Autopsy Report.

Blood Chemistry

It appears the Ms. Nance has a serious problem. We'll start over. Click the **Restart** main menu selection to restart Ms. Nance.

Blood chemistry may be helpful. Go to the  Blood And Urine Samples panel.

Check blood electrolytes. Click Take Sample Now in the Venous Blood Sample box. Are the blood electrolytes normal?

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Ms. Nance** | **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 | % |

Get arterial blood gases. Click Take Sample Now in the Arterial Blood Gases box. Are there abnormal values here?

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Ms. Nance** | **N. Subject** | **Units** |
| pO2 |  | 94 | mmHg |
| [O2] |  | 0.20 | mL/mL |
| Saturation |  | 98 | % |
| pCO2 |  | 38 | mmHg |
| pH |  | 7.44 | pH Units |
| [H+] |  | 36 | pMol/L |
| [HCO3-] |  | 26 | mEq/L |

What is a possible connection between the arterial blood values observed above and our initial observation of respiratory rate?

Get venous blood gases. Click Take Sample Now in the Venous Blood Gases box. Are there abnormal values here?

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Ms. Nance** | **N. Subject** | **Units** |
| pO2 |  | 39 | mmHg |
| [O2] |  | 0.15 | mL/mL |
| Saturation |  | 73 | % |
| pCO2 |  | 43 | mmHg |
| pH |  | 7.39 | pH Units |
| [H+] |  | 41 | pMol/L |
| [HCO3-] |  | 27 | mEq/L |

Exercise Tolerance

Next we will evaluate Ms. Nance's tolerance to exercise. We'll use the treadmill and gradually increase the slope or grade of the belt.



The protocol (shown above) is to advance the solution for 1 minute at each treadmill grade and to record heart rate at the end of the minute. Then increase the treadmill grade and repeat until either the protocol is complete or Ms. Nance stops exercising.

Record Ms. Nance's initial, or resting, heart rate in the table below (at 0’). Then go to  Exercise.

Set exercise type to treadmill. Set treadmill speed to 6 MPH. Initially set treadmill grade to 0%. Advance the solution for 1 minute. Record heart rate. Increase the treadmill grade and repeat.

Norm S. = Heart rate data for Norm Subject.

X = Could not complete the protocol.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Time | 0’ | 1’ | 2’ | 3’ | 4’ | 5’ |
| Speed | 0 | 6 | 6 | 6 | 6 | 6 |
| Grade | 0% | 0% | 2% | 4% | 6% | 8% |
| Norm S. | 73 | 124 | 137 | 142 | X | X |
| Heart Rate |  |  |  |  |  |  |

Invasive Studies

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

Click the **Restart** main menu selection to restart Ms. Nance.

Go to  Flow and record cardiac output, stroke volume and heart rate. This is clearly a low flow condition caused by a diminished stroke volume.

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Ms. Nance** | **N. Subject** | **Units** |
| Cardiac Output |  | 5360 | mL/Min |
| Stroke Volume |  | 73 | mL |
| Heart Rate |  | 73 | /Min |

Various Blood Pressures

Go to  Pressure and record the blood pressures at various locations in the circulation.

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Ms. Nance** | **N. Subject** | **Units** |
| Syst. Arteries. |  | 97 | mmHg |
| Perph. Veins |  | 7.3 | mmHg |
| Portal Vein |  | 8 | mmHg |
| Right Atrium |  | 0.3 | mmHg |
| Pulm. Artery |  | 13 | mmHg |
| Pulm. Caps |  | 9 | mmHg |
| Pulm. Vein. |  | 5.7 | mmHg |
| Left Atrium |  | 3.7 | mmHg |

Pressures in the systemic circulation and right atrium are not entirely normal, but seem to be OK. In contrast, pressures in the pulmonary circulation and left atrium are markedly elevated.

There are 2 stories developing here:

1. There is something seriously wrong with Ms. Nance's left heart.
2. There is a threat that pulmonary edema might develop.

Pressure And Volume In The Left Heart

Go to  Pumping and note the end-diastolic (ED) and end-systolic (ES) pressures and volumes. Calculate or observe Ms. Nance's ejection fraction.

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Ms. Nance** | **N. Subject** | **Units** |
| EDP |  | 3.2 | mmHg |
| EDV |  | 121 | mL |
| ESP |  | 123 | mmHg |
| ESV |  | 48 | mL |
| Stroke Volume |  | 73 | mL |
| Ejection Fraction |  | 61 | % |

What is your diagnosis at this point? Have you considered stenosis of the aortic valve? Why.

Left Heart Contractility And Coronary Flow

Go to  Muscle and note myocardial contractility and the effect of pH on contractility.

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Ms. Nance** | **N. Subject** | **Units** |
| Contractility |  | 0.018 | mmHg/mL |
| pH Effect |  | 1.0 | x Normal |

We're getting close to an explanation.

Use the **View / Organ Details** main menu selection to install the organ details toolbar buttons.

Go to  (yellow heart) Circulation and note the blood flow to the left heart. Go to Metabolism and note the metabolic rate, tissue pH and tissue lactate concentration.

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Ms. Nance** | **N. Subject** | **Units** |
| Blood Flow |  | 180 | mL/Min |
| Metabolic Rate |  | 129 | Cal/Min |
| pH |  | 6.98 | mmHg |
| [Lac-] |  | 2.0 | mEq/L |

We are looking at a failing, acidotic, somewhat anaerobic left heart.

Salt And Water Balance

Salt and water retention is often an integral part of heart failure. We'll check on Ms. Nance.

Go to  Diet and note daily sodium intake. Then go to  Urine and note sodium excretion rate.

Na+ Output \_\_\_\_ mEq/Min x 1440 = \_\_\_\_ mEq/Day

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Ms. Nance** | **N. Subject** | **Units** |
| Na+ Intake |  | 180 | mEq/Day |
| Na+ Output |  | 180 | mEq/Day |

There is a major sodium imbalance here. Where is that sodium going?

Body Fluids

The sodium picture above suggests that one or more volumes in the body are abnormal.

Go to  Blood Volume and note the volume and composition of the blood.

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Ms. Nance** | **N. Subject** | **Units** |
| Blood Volume |  | 5400 | mL |
| Red Cells |  | 2400 | mL |
| Plasma Volume |  | 3000 | mL |

Go to  Water and record the volumes of important body fluid compartments.

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Ms. Nance** | **N. Subject** | **Units** |
| Total Body H2O |  | 43.2 | L |
| ECFV |  | 15.0 | L |
| Plasma |  | 3.0 | L |
| Interstitium |  | 12.0 | L |
| Excess Lung |  | 0.0 | L |
| Ascites |  | 0.0 | L |
| Cell H2O |  | 28.2 | L |

The picture is now getting clearer. It appears that Ms. Nance's kidney is avidly retaining salt and water and much of this salt and water, in turn, is spilling into the lungs. Our last stop will be the pulmonary capillaries.

Pulmonary Capillaries

Go to  Lung Fluids and note the hydrostatic pressure in the capillaries and the colloid osmotic pressure.

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Ms. Nance** | **N. Subject** | **Units** |
| Hydrostatic Pressure |  | 9 | mmHg |
| Plasma COP |  | 28 | mmHg |
| Filtration |  | 0 | mL/Min |

The long-term problem then is heart failure, while the acute problem is the formation of pulmonary edema.

Treatment

Create a treatment strategy that stabilizes (or possibly improves) Ms. Nance's condition over 1 month. Diuretics, digitalis and other treatments are available at  and . Gas can be administered at  Air Supply. Changes in environment and diet might also be considered.

Ms. Nance - Notes

Ms. Nance’s thumbnail sketch notes that she’s tired and can’t get enough air.

In fact, Ms. Nance is in heart failure.

Creating Ms. Nance

This is a new look Ms. Nance who shows weight gain, peripheral edema, and the start of pulmonary edema. She has bilateral dysfunction that has both systolic and diastolic components.

The new parameter values are:

“Right Heart Contractility, Basic (%)” = 50.0

“Right Heart Pumping, Stiffness” = 0.0132

“Left Heart Contractility, Basic (%)” = 50.0

“Left Heart Pumping, Stiffness” = 0.0227

Advance the solution 2 weeks (20160 minutes).

Ms. Nance is ready.

Recap

Chronic bilateral heart failure impaired diastolic filling and impaired systolic ejection. This lowers stroke volume, cardiac output and arterial pressure. The kidneys retain salt and water, expanding blood and interstitial volume.

Expanded blood volume and redistribution of blood volume enhance left ventricular filling. This, in turn, increases stroke volume, which is small but otherwise would be even smaller.

The left and right ventricles operate at increased end-diastolic and end-systolic volumes and a reduced ejection fraction.

Increased left and right heart filling pressure is possible only when blood pressure is increased in all of the pulmonary circulation and in the peripheral veins.

When blood pressure in the pulmonary capillaries exceeds colloid osmotic pressure in the blood, fluid rapidly ultrafilters into the lungs. This pulmonary edema impairs the diffusion of O2 and CO2 in the lungs and also decreases tidal volume. Blood pO2 falls and deterioration is rapid.

Increased pressure in the peripheral veins leads to the formation of ascites.

Ms. Nance Wrap-up

Summary

Chronic (left side) heart failure lowers stroke volume, cardiac output and arterial pressure. The kidneys retain salt and water, expanding blood volume.

Expanded blood volume and redistribution of blood volume enhance left ventricular filling. This, in turn, increases stroke volume, which is small but otherwise would be even smaller.

The left ventricle operates at increased end-diastolic and end-systolic volumes and a reduced ejection fraction.

Increased left heart filling pressure is possible only when blood pressure is increased in all of the pulmonary circulation.

When blood pressure in the pulmonary capillaries exceeds colloid osmotic pressure in the blood, fluid rapidly ultrafilters into the lungs. This pulmonary edema impairs the diffusion of O2 and CO2 in the lungs and also decreases tidal volume. Blood pO2 falls and deterioration is rapid.

Postscript

Ms. Nance's condition was caused by atherosclerosis in the coronary vessels feeding her left heart. Go to  (yellow heart) Circulation and note the value of large vessel conductance. A normal value is 20.