Introduction

Minimal cardiovascular system (CVS) function as often lead to challenging issues in understanding the behavior of the cardiovascular system. Therefore, the need for a mathematical model of the cardiovascular system is significant. This model would be an important tool for the cardiologists in understanding, diagnosis and treatment selection for CVS dysfunctions. This research investigates the ability of a minimal cardiovascular system model to simulate diseases affecting the cardiovascular system.

Method

A minimal approach has been taken to modeling the cardiovascular system using a small number of governing equations and parameters. Minimal parameters are adjusted to simulate a variety of CVS disease states found in literature. Simulation results are compared with known physiological responses.

Case studies included:
- Aortic valve stenosis
- Hypertension
- Heart failure
- Hypotension
- Shock

Mathematical model of the CVS would help medical staff and researchers delineate the relative effects of a variety of dysfunctions and reflexes on CVS haemodynamics. The research would be valuable for researchers in understanding, diagnosis and treatment selection for CVS dysfunctions.

Aim to assist medical staff, students and researchers in understanding, diagnosis and treatment selection for CVS dysfunctions.

Valvular Dysfunction Simulation

Aortic Stenosis

Scenario:
- Gradual stenosis on the aortic valve leading to a decrease in the valve’s ability to open properly.

Pathophysiology:
- Blood pressure and cardiac output change minimally. However, systolic blood pressure increases significantly due to increased afterload.

Treatment:
- SAGE replacement.

Aortic Regurgitation

Scenario:
- The aortic valve becomes damaged and will not close properly. Blood is able to flow back into the ventricle during diastole, but with a much higher resistance of 7 times that of forward flow.

Pathophysiology:
- The left ventricle pressures increase significantly due to increased afterload.

Treatment:
- SAGE replacement.

Aortic Hypertrophy

Scenario:
- The heart muscle is stressed blood volume.

Pathophysiology:
- Mean arterial pressure decreases and the aortic valve velocities are reduced due to decreased arterial stiffness.

Treatment:
- Reduce venous dead space through venous vasoconstriction.

Heart Failure Simulation

Scenario:
- Heart failure results in stress on the heart due to a blockage in the coronary artery. Contractility is reduced by a factor of 4 and diastolic elastance is increased by 35%.

Pathophysiology:
- The left heart receives an inadequate supply of oxygen due to a blockage in the coronary artery.

Treatment:
- Beta-blockers. To reduce right ventricle activity causing lower pulmonary pressures and slow the sick left ventricle.
- Diuretics. To reduce stressed blood volume, lowering pulmonary pressures and reducing fluid buildup in the lungs.

Hypovolemic Shock Simulation

Scenario:
- Significant blood loss due to hemorrhage. Total blood volume is reduced by 50%.

Pathophysiology:
- Blood pressure at 80mmHg.

Treatment:
- Increase blood volume.