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Fluid continuity equation simulation: Monitoring fluid reservoir volume in the heart over time

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ABSTRACT

Fluid flowing in a cross-section of a channel follows the law of continuity, namely the mass rate of fluid entering will be the same as the mass rate of fluid leaving. One of the applications of fluid flow is in human blood flow. Blood flow is controlled by the heart which functions to pump blood to and from the heart. The flow of blood entering and leaving the heart is determined by the cross-sectional area of the channel and the speed of blood flow through the heart. The speed of blood flow in the heart consists of two speeds, namely the systolic speed when blood leaves the heart and the diastolic speed when blood enters the heart. So that the volume in the heart can be observed changes over time. By creating a simulation using the MATLAB programming language, the difference between normal heart volume and problematic heart volume can be known. A program called reservoir and cardiac based on graphical user interface was created to determine the volume of fluid in the reservoir at any time and compare the volume of fluid in normal and abnormal hearts concerning time in 1 systole-diastole cycle.

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1. INTRODUCTION

Fluid flowing in a cross-section of a channel follows the law of continuity, namely the mass rate of fluid entering will be the same as the mass rate of fluid leaving [1-5]. One of the applications of fluid flow is in human blood flow [6-8]. Blood flow is controlled by the heart which functions to pump blood to and from the heart [9-13]. The flow of blood entering and leaving the heart is determined by the cross-sectional area of the channel and the speed of blood flow through the heart [14-17].

The speed of blood flow in the heart consists of two speeds, namely the systolic speed when blood leaves the heart and the diastolic speed when blood enters the heart [18-21]. So that the volume in the heart can be observed changes over time [22-25]. The speed of systole and diastole is different for each individual, by simulating the heart volume against time in normal conditions and comparing it with certain conditions so that the differences can be observed it is hoped that it can be used to detect whether the blood flow can be categorized as normal or not so that it can be used to detect heart abnormalities. Simulation can make it easier to detect differences in the volume of a normal heart and a problematic heart through a program so that it is hoped that we can find out the problems that occur in the heart.

2. RESEARCH METHODS

Simulation of the fluid continuity equation by monitoring the volume in the reservoir and the fluid volume in the heart was created using the MATLAB programming language. MATLAB is a programming language that comes with functions and characteristics that are different from other existing programming languages.

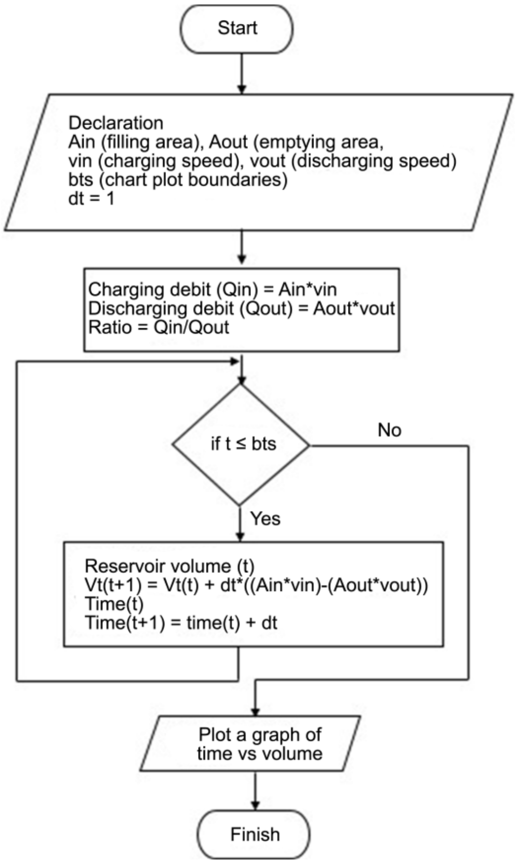

Figure 1. Flowchart for the reservoir program.

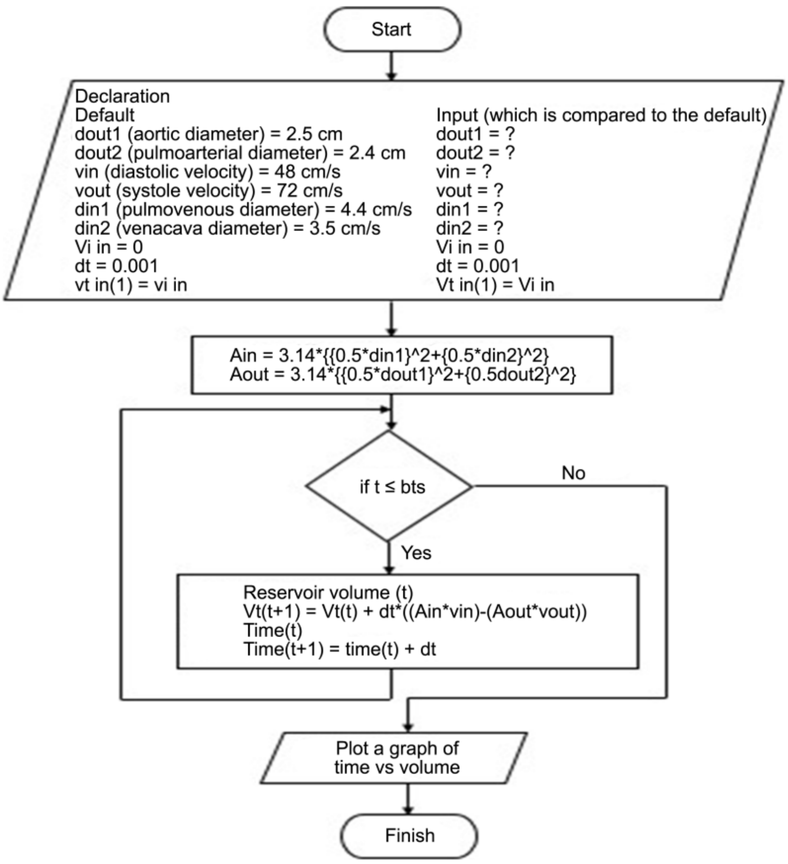

Figure 2. Flowchart for the cardiac program.

MATLAB is a high-level programming language specifically for technical computing, visualization, and programming needs such as mechanical computing, data analysis, algorithm development, simulation and modeling as well as calculation graphics. This fluid continuity equation simulation program uses a numerical approach and uses the Euler method in its equations. This program is structured in several stages, namely gather information, create an algorithm, create a program design, create a program, validation, trial, and design improvements (see Figure 1 and 2).

3. RESULTS AND DISCUSSIONS

A MATLAB graphical user interface (GUI) based program has been created with the name reservoir as in Figure 3. The reservoir program is to simulate fluid volume versus time in a reservoir. From this program, we can know the volume of fluid in the reservoir at any time, the time when the reservoir is full, and so on.

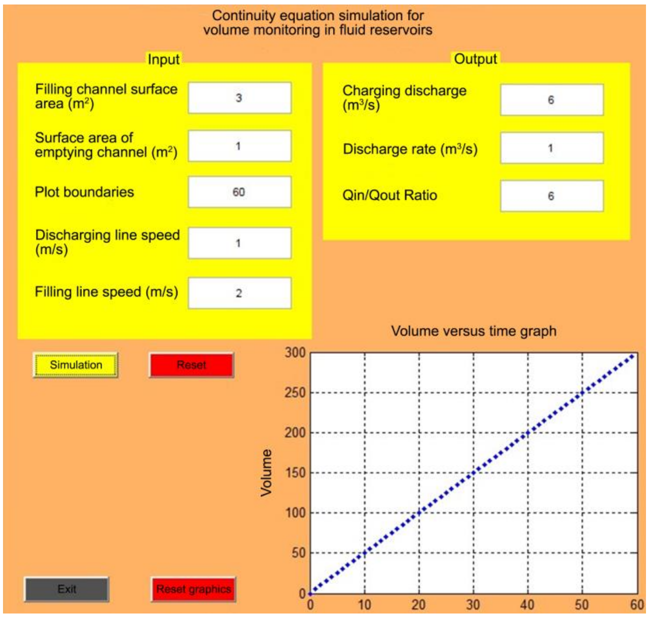

Figure 3. Graph of fluid volume against time in a reservoir.

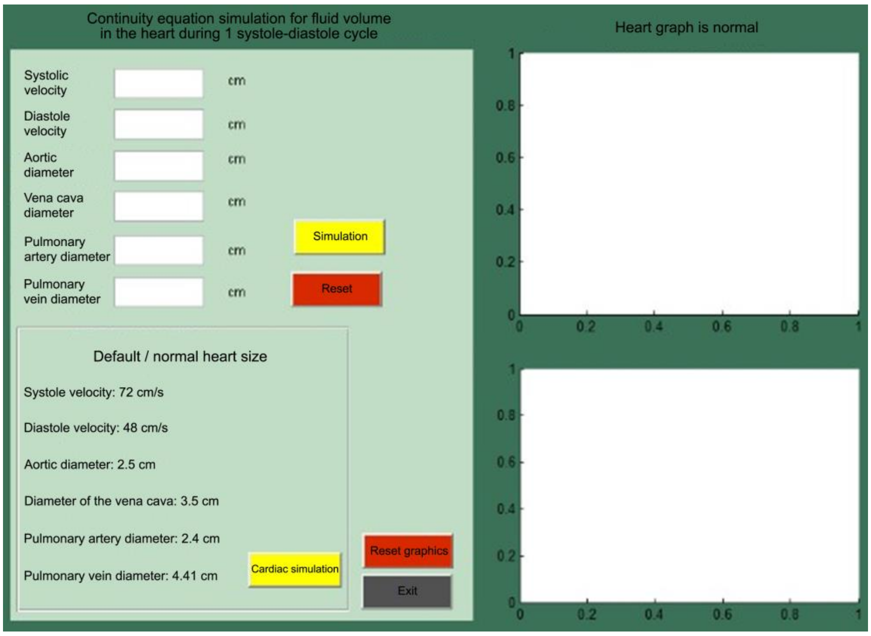

Figure 4. MATLAB GUI-based *cardiac.fig* program.

Meanwhile, to simulate the fluid volume in the heart, the *cardiac.fig* program in Figure 4 has been created, which is also based on the MATLAB GUI. In the GUI there are two graphs, namely a graph that simulates the volume of fluid in the heart against time with variable values for a normal heart without disorders (default). These variable values include systolic velocity, diastolic velocity, aortic diameter, vena cava diameter, pulmonary artery diameter, and pulmonary vein diameter. Meanwhile, in another graph, the volume of fluid in the heart is simulated with the values of these variables being changed.

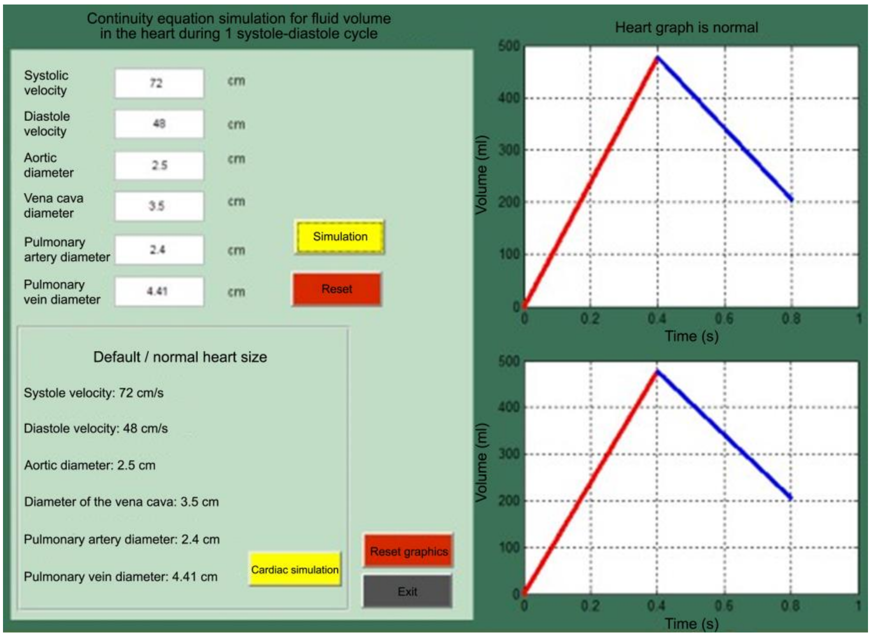

Figure 5. Graph of fluid volume in a normal heart versus time in one systole-diastole cycle.

In Figure 5, the GUI section with variable values that can be changed is first filled in with the default values for a normal heart. The resulting two graphs produce the same curve, which shows that the program is running well. Then, the program enters variable values that are different from the default normal heart with the following Figure 6.

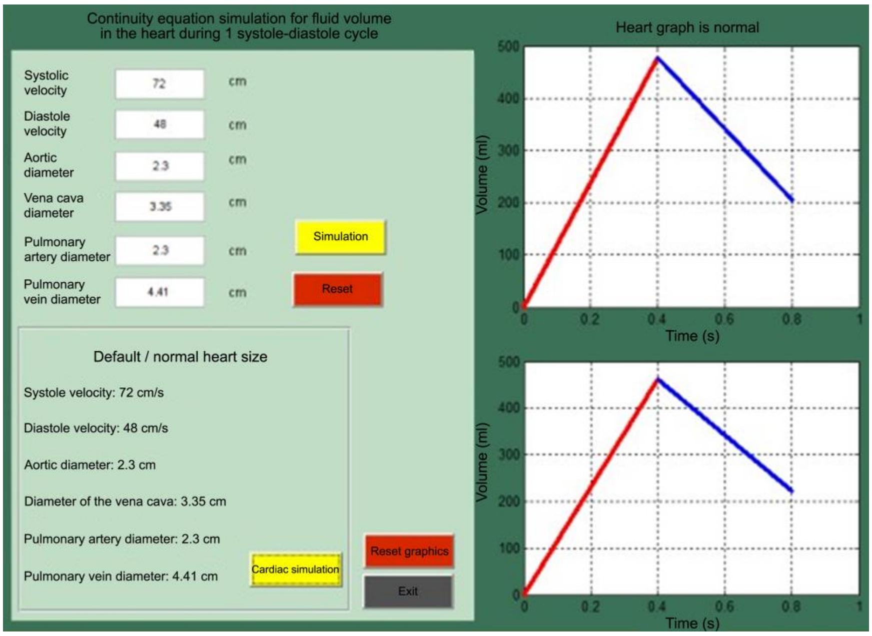

Figure 6. Comparison graph of fluid volume in a normal heart and an abnormal heart.

Thus, with this program it is possible to compare the condition of the fluid volume in a normal heart and an abnormal heart in one systole-diastole cycle, that is, with the input variables changed according to the condition of the heart to be simulated.

4. CONCLUSION

The *reservoir.fig* program simulates fluid volume versus time in a reservoir. From this program, we can know the volume of fluid in the reservoir at any time, the time when the reservoir is full, and so on. The *cardiac.fig* program can simulate a graph of fluid volume in a normal and abnormal heart versus time in 1 systole-diastole cycle so that it can also be compared. This is done by filling in the input variables according to the condition of the heart to be simulated.

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