Cardiovascular Interactions Tutorial: An Update

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ABSTRACT:

The Cardiovascular Interaction (CVI) simulation model was developed by Carl Rothe (1929-2016) as an interactive computer simulation in the form of a tutorial. The original tutorial was based on a five-compartment model (Venous Bed, Right Heart, Lung Bed, Left Heart, and Arterial Bed). This work examines the simulation Dr. Rothe developed based on a six-compartment model (Systemic Veins, Right Ventricle, Pulmonary Arteries, Pulmonary Veins, Left Ventricle, and Systemic Arteries). Both models were originally developed in Visual Basic. Both models have been reimplemented in C# WPF for Windows and in LabVIEW for Windows 10 and Mac OS X.

INTRODUCTION:

The goal of the CVI (Cardiovascular Interaction) project was to develop a computerized tutorial to allow learners (users) to investigate the integration and control of the cardiovascular system. Recent publications in *Advances in Physiology Education* are concluding that new methods for teaching physiology are more effective than old ones if they get students actively involved [1]. Rothe's models and the Lab Book can be used either for classroom discussions or for self instruction. Both ways of using his models can get students actively involved. This goal has not changed; however, it was necessary to update the implementation to continue to attain this goal.

The original five-compartment model, discussed in references [2] and [3], was a two-part implementation consisting of a Lab Book in the form of a tutorial as a Microsoft Word document that drives the cardiovascular simulation model. The six-compartment model had a similar structure. Both models were implemented in Visual Basic. Due to changes in the Windows operating system, the interactive tutorial is no longer functional. The models, however, are fully functional and can stand alone.

A recent effort was undertaken to reimplement the cardiovascular simulation models so they can be run on the current operating systems. (The Lab Book can still be followed, and the learner still gets the benefit of that process.) While updating the implementation of the models, it was discovered that information on the six-compartment model had never appeared in the literature. The focus of what follows is the six-compartment model.

The computational results for both the five and six compartment models for the three implementations (C# Windows Presentation Foundation, and LabVIEW for both Windows and Mac OS X) have been validated against the original Visual Basic implementations.

SIX-COMPARTMENT MODEL:

The Six-Compartment model has additional features not included in the five-compartment model discussed in references [2] and [3]. Additional detail involving modeling the systemic and pulmonary circulations has been added.

Using the same experiment from the Lab Book cited in [2] involving left ventricular failure, the experiment involves reducing E_{max} to 14% of normal for the left ventricle. Emax is the ventricular contractility. The following results were produced by the three different implementations: Rothe's original Visual Basic implementation, recoded C# version, and the new LabVIEW implementation.

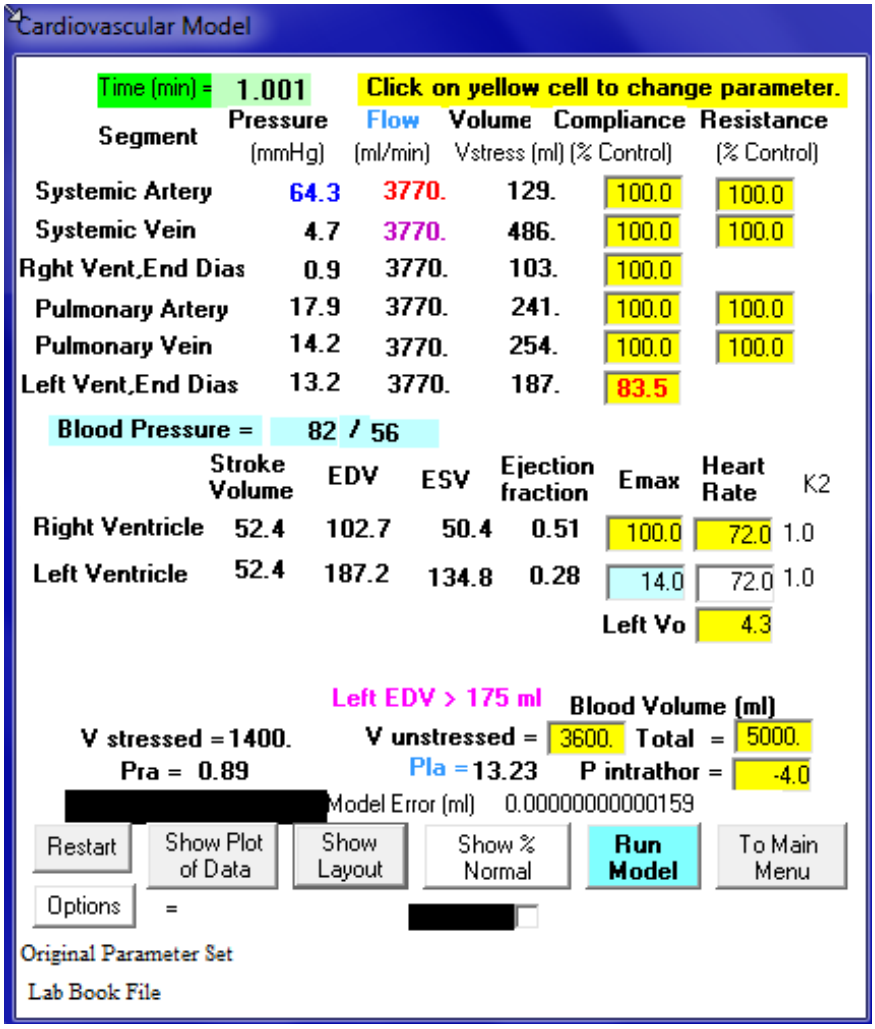

Figure 1: Rothe's Visual Basic implementation - Model display during left ventricular failure (E_{max} 14% of normal for the left ventricle);

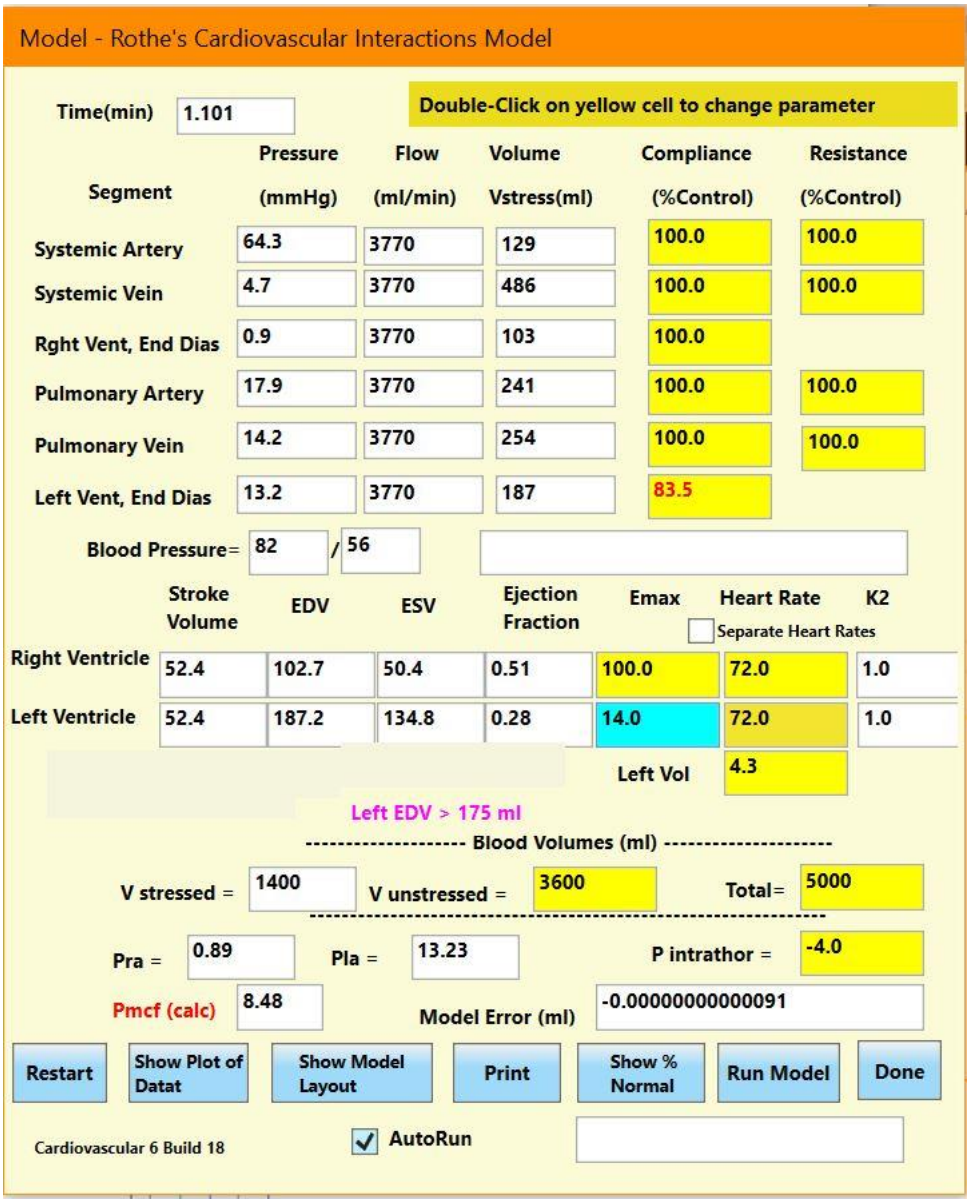

Figure 2: C# implementation - Model display during left ventricular failure (E_{max} 14% of normal for the left ventricle);

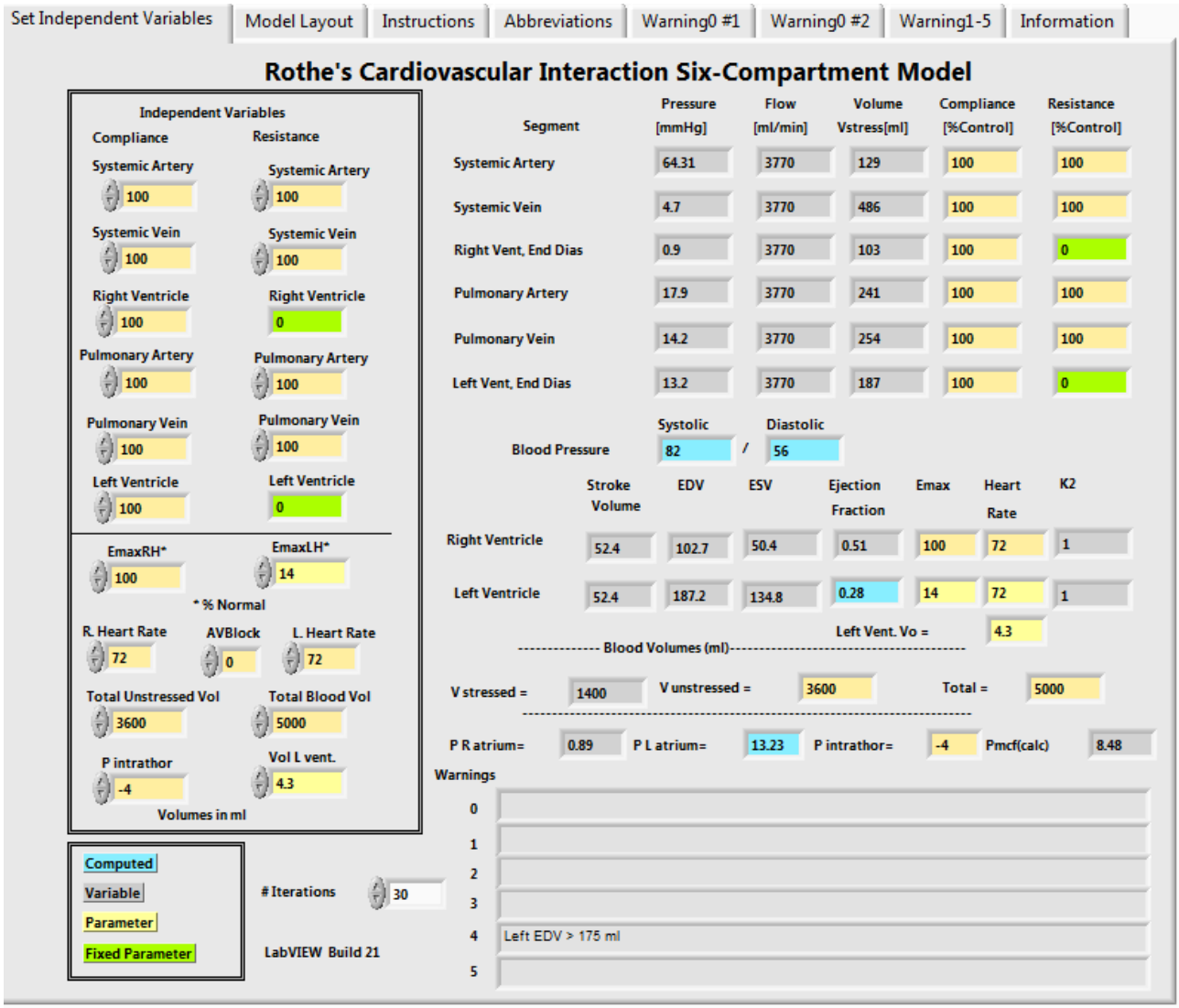

Figure 3: LabVIEW implementation - Model display during left ventricular failure (E_{max} 14% of normal for the left ventricle)

The displays in Figures 1 – 3 allow the user to change one or more of the independent variables in the simulation (highlighted with a color background). Independent variables can be changed in sequence to carry out the more complex experiments posed in the Lab Book.

Each of the implementations also has a second display providing more detailed information about the cardiovascular system. Figure 4 is the model layout display from the C# implementation

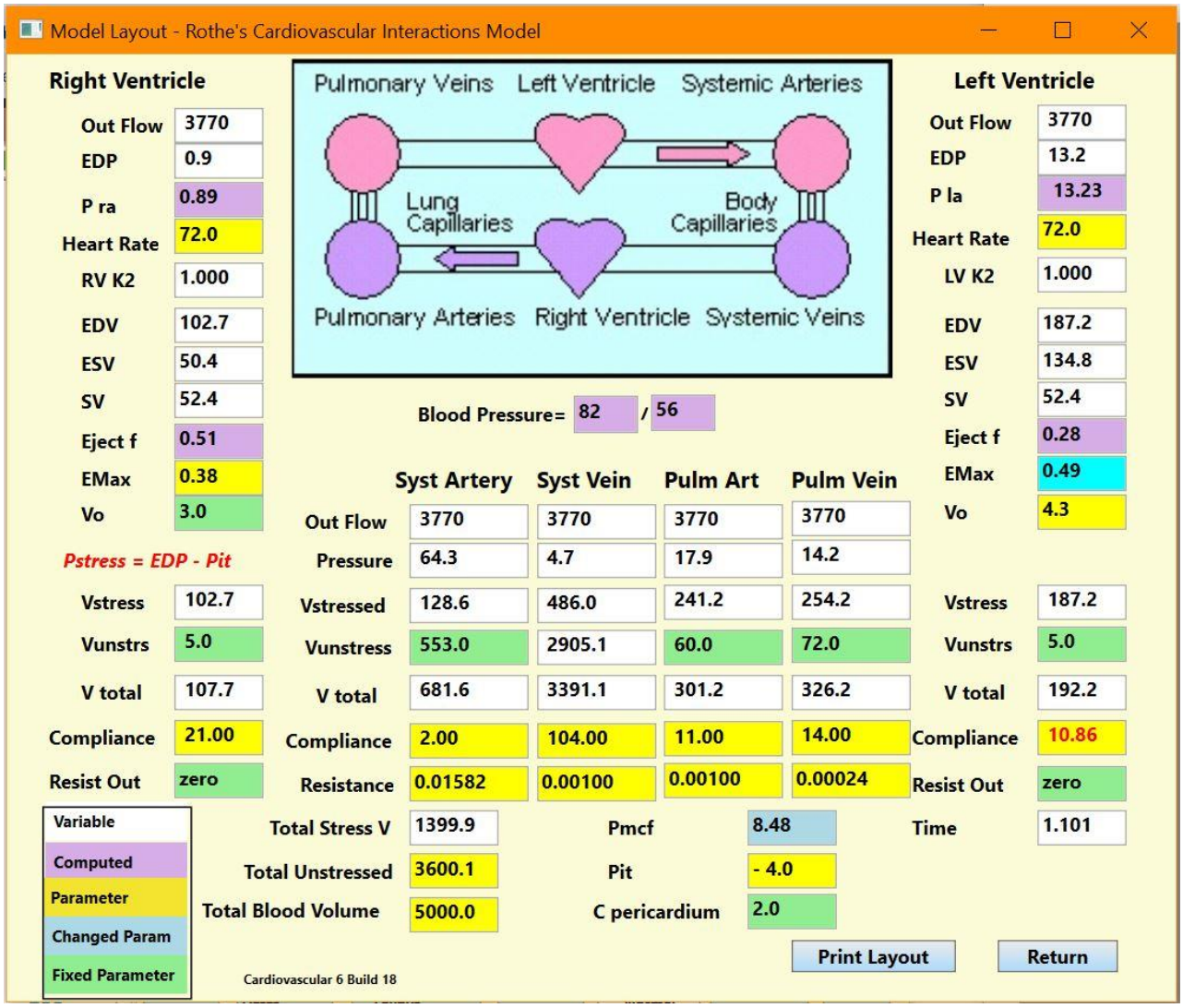

Figure 4: Model Layout display from the C# implementation.

The C# implementation also includes the plot option from the Visual Basic version (Figure 5).

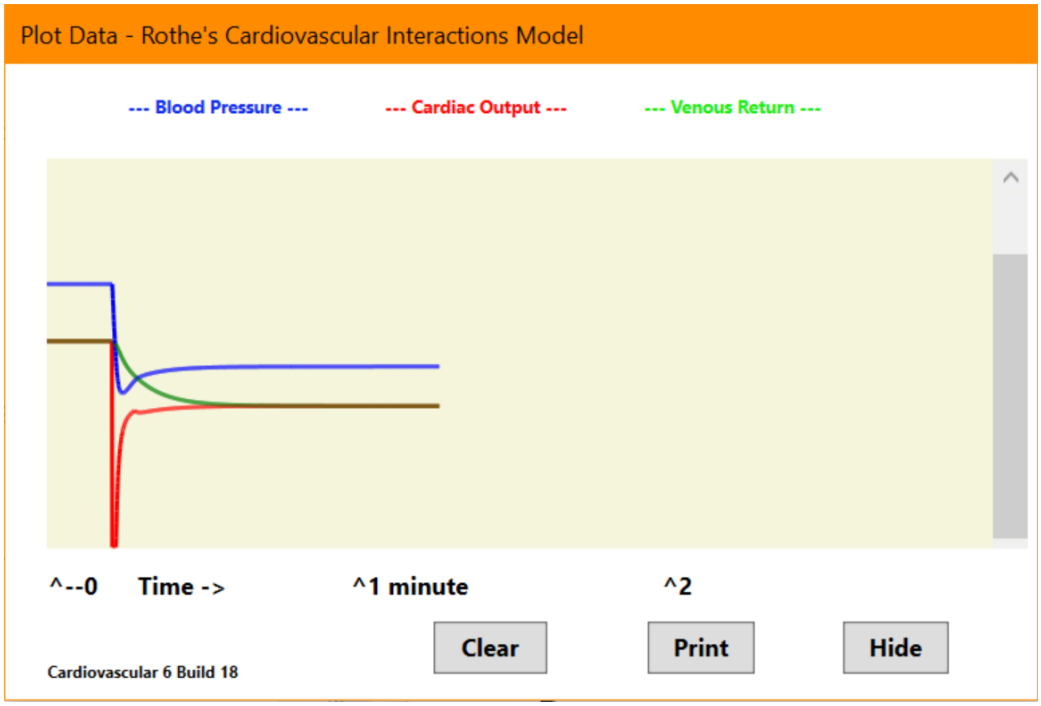

Figure 5: Plot from the C# implementation.

FINAL THOUGHTS:

The updated versions of Carl Rothe's Cardiovascular Simulation mode have been validated against the original Visual Basic versions of the code. The updated versions will all run on current versions of the Windows operating system and there is a LabVIEW version that will run on Mac computers under OS X.

The updated versions can run the experiments suggested in the Lab Book mentioned in [2] without the integrated interface.

The updated code and the original Visual Basic versions are available at the Life Sciences Teaching Resource Community (LifeSciTRC) digital library:

http://www.lifescitrc.org/resource.cfm?submissionID=10473

REFERENCES

1. Luchi, K., Montrezor, L. and Marcondes, F., Effect of an educational game on university students' learning about action potentials, *Advances in Physiology Education*, 41: 222-230, 2017.

2. Gersting, J. M and Rothe, C. F., Cardiovascular Interactions Tutorial: Architecture and Design, *Journal of Medical Systems*, 26: 29-38, 2002.

3. Rothe, C. F. and Gersting, J. M., Cardiovascular Interactions: An interactive tutorial and mathematical model, *Advances in Physiology Education*, 26: 98-109, 2002.