Parameter Identification in a Model of the Cardiovascular System Including the Atria

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Introduction

Cardiovascular system (CVS) dysfunctions are a major cause of intensive care unit admissions. In these units, clinicians only have access to a limited amount of data. The use of patient-specific models to assist clinicians offers real perspectives. As the atria play an important role in cardiac function, introducing them in an existing lumped computer model of the cardiovascular system can provide useful information.

Methods

- Two new elastic chambers representing the atria are added to the initial six-chamber model of the CVS proposed by Smith *et al.* [1], see Fig. 1.
- Pressure and volume in the atria are related by a time-varying elastance:

$$E(t) = E_{passive} + E_{active}.e(t-\Delta t)$$

  where $e(t)$ is the ventricular driver function
  and Δt is the delay between atrial and ventricular contraction.
- Parameter identification method proposed by Revie *et al*. [2]:

$$param^{new} = \frac{measurement}{model\ output}\, param^{old}$$

- Application to atrial parameters (see Fig. 2):
  - $E_{active} \propto$ ventricular peak pressure during atrial contraction,
  - R_{pu} and $R_{vc} \propto$ minimum of ventricular pressure,
  - $\Delta t \approx$ duration of ventricular systole.

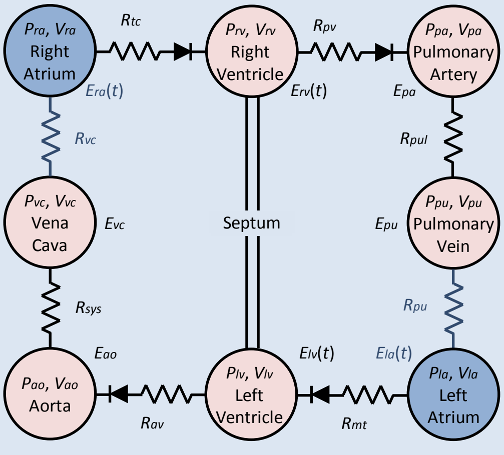

Fig. 1: CVS model including the atria. Elements added to the initial model are shown in blue.

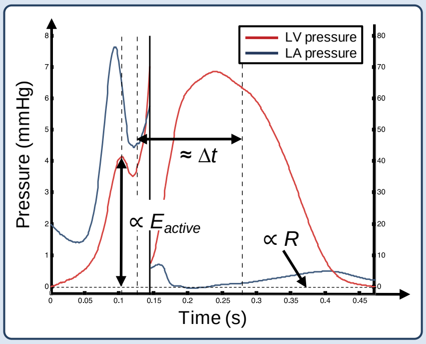

Fig. 2: Summary of the identification process for (left) atrial parameters. The vertical full line separates the two pressure scales used for the graph. The vertical dashed lines indicate maximum of ventricular pressure during atrial contraction, beginning and end of ventricular systole, respectively.

Results

The original and extended identification methods have been applied to experimental measurements carried on pigs in order to check the results and observe the influence of adding the atria in the model.

The introduction of the atria does not cause an important increase of the errors (less than 10 %).

The result of the identification for the left ventricular P-V loop is shown in Fig. 3.

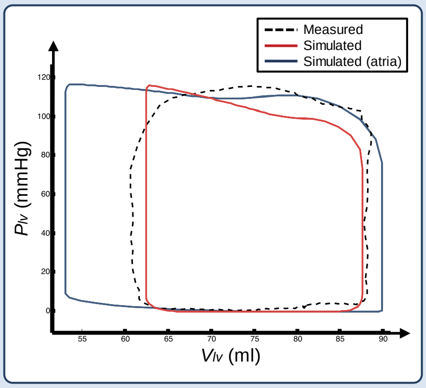

Fig. 3: Result of the identification for the left ventricular P-V loop.

Conclusions

The interest of the method developed in this work is significant since it gives supplementary information (about the atria) without importantly increasing the errors and without imposing the need for new measurements.

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References

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