An *in silico* model to detect cardiovascular disease through effective pulse wave analysis

INSIGNEO
Institute for *in silico* Medicine

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Background

Blood pulse waveforms contain information about the system through which they propagate. They are the result of the superposition of incident waves coming from the heart and reflected waves generated in the proximity of a mechanical discontinuity. Cardiovascular pathologies such as aneurysms and stenoses can be seen as discontinuities in the circulation topology and its mechanical properties, which, in turn, may modify the shape and the amplitude of pulse waveforms.

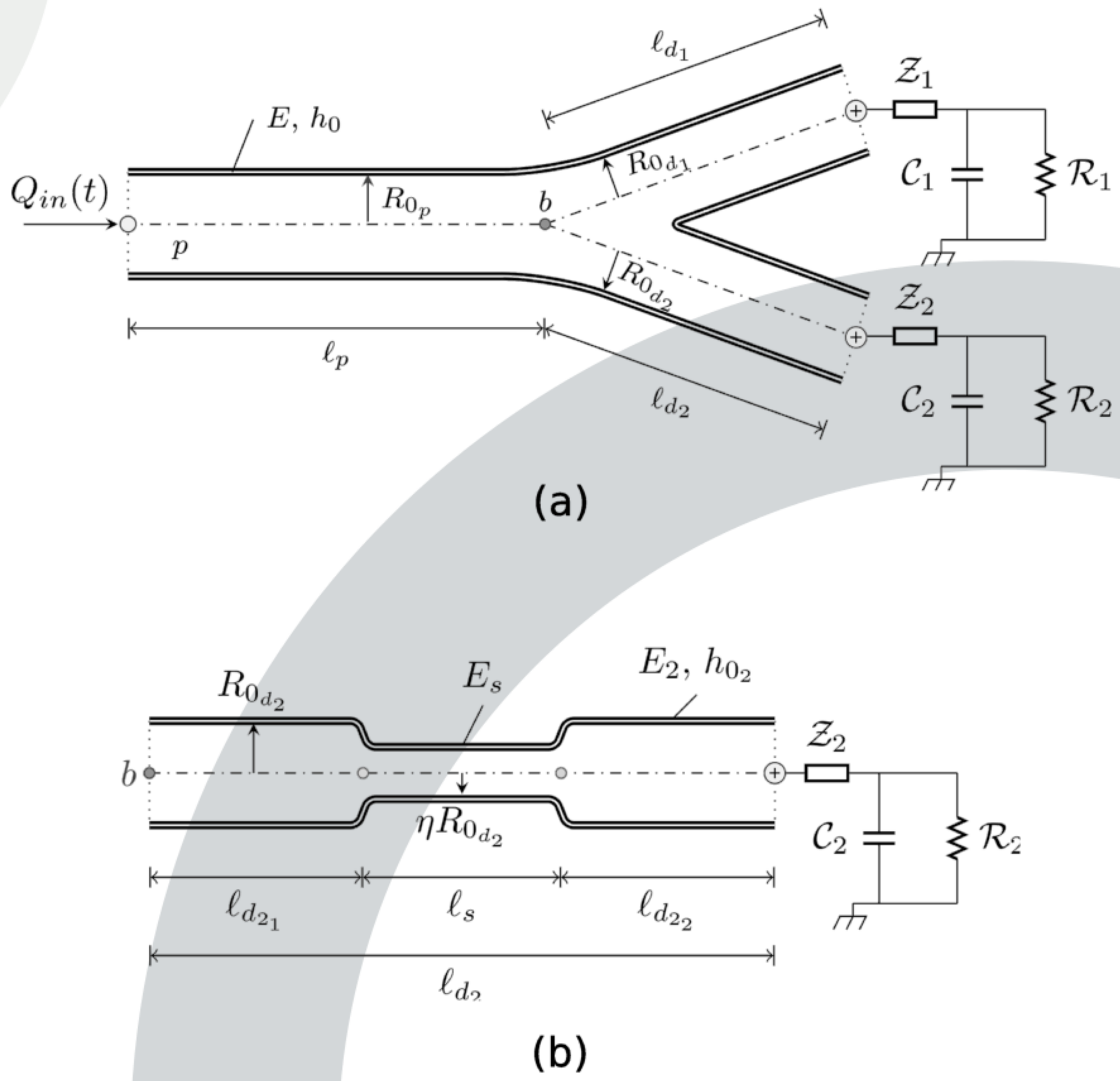

Figure 1. (a) Bifurcation vascular network. From the parent vessel *p*, two daughter vessels $d_{1,2}$ branch out. The two outlets are coupled with a 0D model of the peripheral vasculature. The measurement point is located at the middle of the parent vessel. (b) Portion of the computational domain where the geometrical discontinuity is introduced as either a stenosis (η<1) or an aneurysm (η>1).

Methods

Waveforms propagation within a bifurcating arterial tree (Figure 1) is simulated by means of numerical techniques. The mapping is achieved by simulating several configurations of the arterial tree, i.e. a discontinuity like a stenosis is placed in a single vessel and its radius is changed within a clinical range. Hence, the location and extent of the discontinuity can be related to variations of the waveforms. Eventually, the mapping allows to operate an inverse analysis of the waveform. A Gaussian process statistical emulator is used to characterise the vascular model and run the analysis more efficiently.

Results

Results show that pressure waveforms taken at the root of the simulated vascular network allow to distinguish the presence of a stenosis (vessel constriction) from a fusiform aneurysm (vessel dilation) (Figure 2). Different patterns of blood pressure and blood flow occur in the two cases. The aneurysm causes an increase of the minimum increase and a decrease of the maximum pressure. The stenosis is correlated with a decrease in flow in the affected vessel.

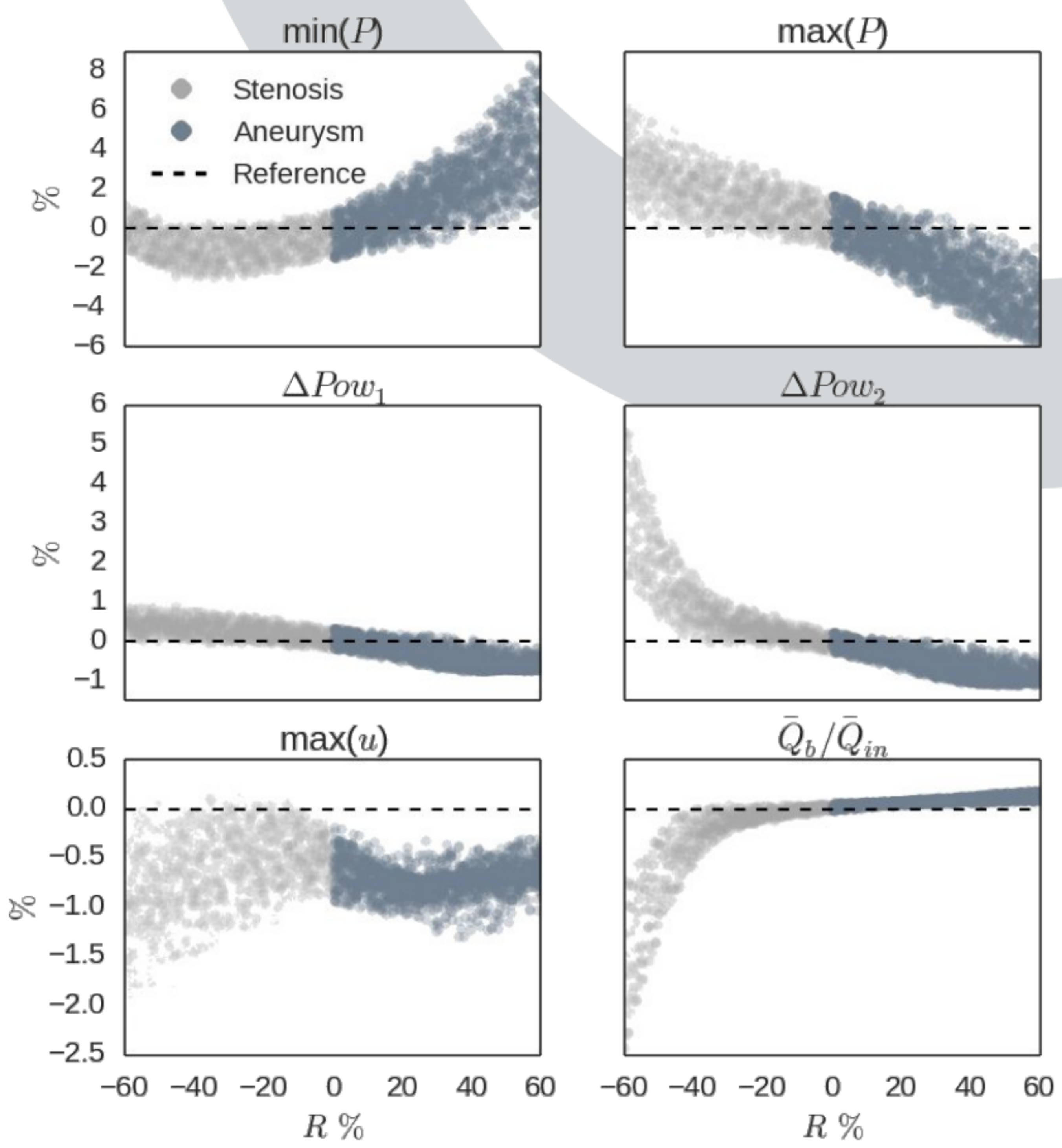

Figure 2. Pressure (P), flow (Q), and velocity (u) waveforms features are analysed as the change in radius occurred. Results allow to tell apart between a stenosis and a fusiform aneurysm.

Conclusions

Numerical simulations are conducted by means of a finite volume solver developed in INSIGNEO to study blood pulse waveforms propagation within the arterial vasculature. The extent of the vascular condition can be inferred from waveforms analysis. Further development and use of these techniques may ultimately allow us to develop the next generation of monitoring devices (e.g. wearable sensors) to detect cardiovascular pathologies from an early stage when still treatable.

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