Electric analogue and hyperbolic models for liver hemodynamics during partial hepatectomy

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Partial ablation of the liver surgery is needed to treat some liver pathologies. Due to liver complex blood perfusion, the surgery induces important pressure and flow changes for the remaining liver. The functional regeneration of the liver seems sensitive to these changes. A non-functional regeneration of the liver can put patient health in danger. In this context, the hemodynamics changes occurring during liver partial ablation, are studied with mathematical models.

First, a 0D closed-loop model of cardiovascular and liver blood circulation, based on ordinary differential equations, is developed. Surgery impacts on total circulation is modeled. Infusion and bleeding phenomena can be captured. The obtained differential algebraic system of equations, is solved with backward differentiation formula and the resulting nonlinear system is then solved with a Newton method [1]. Averaged simulated values are in good agreement with experimental measurements.
Then, in order to study the effects of liver partial ablation on pressure and on flow waveforms, the main arteries are modeled with nonlinear hyperbolic 1D equations. These equations are coupled with the 0D closed-loop model. The nonlinear hyperbolic 1D equations are solved with a kinetic scheme. The solution of 0D closed-loop model equations and the coupling are computed with a Newton method. The key changes observed during surgery are reproduced. Moreover, transport of contrast product in the main arteries, based on blood flow, can be modeled. The different models are used to study the impact of liver partial ablation, and are compared with experimental measurements.

Références

[1] Hindmarsh AC, Brown PN, Grant KE, Lee SL, Serban R, Shumaker DE, Woodward CS, *SUNDIALS: Suite of nonlinear and differential/algebraic equation solvers. ACM Transactions on Mathematical Software (TOMS)*, 2005 (Available from: http://computation.llnl.gov/casc/sundials/main.html).

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