Hyper-simplified cerebrovascular model: High sensitivity of venous pulsatility vs venous resistance

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Background

CCSVI-related increases in extracranial vein resistances (RV) are intensively addressed due to possible correlations with neurodegenerative diseases.[1] Several modelling approaches were adopted to exploit PC-MRA derived arterial, venous, and liquor flows,[2,3] thus pathing the way to parametric identification of major patho-physiological cerebrovascular features. This preliminary work addresses the role of RV in determining the venous pulsatility (VP) in view of future flow data fitting.

Methods

The simplified model includes: i) An arterial Windkessel (WK) compartment with time constant set to 2s; ii) A capacitive shunt from arteries to veins; iii) The output RV. Further simplification was introduced by considering the venous compliance much larger than the arterial one and also that the total resistance was mainly determined by the WK peripheral resistance. The lumped parameter model was simulated by Simulink (Matlab) comparing it to the dynamics of the simplified transfer function (STF).

Results

The STF from arterial pressure (PA) to venous pressure (PV) contains: i) The arterial WK pole; ii) A zero given by the arterial WK compliance times VR; iii) Direct current gain equal to VR over the total resistance. Differences between the STF and the lumped model were negligible. Hence, the main finding is in the zero proportional to VR. This STF features highly affects the gain at the HR (~1Hz) and harmonics. *E.g.*, considering a VR=4 [mmHg/(lt/min)] in normals and 20 in CCSVI the PV/PA gain at HR is increased from 0.24 to 0.78, more than 3-fold.

Conclusions

The work, though still at a purely conceptual level, shows that venous resistance alterations may highly affect the dynamics of venous pressure itself, possibly triggering inflammation processes underlying neurodegeneration. The adopted simplification is also promising in relation to identifiability from real data, by which the model will be challenged in the near future.

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