Pressure alterations along arterial tree during atrial fibrillation

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Atrial fibrillation (AF): the most common arrhythmia

RISKS

- heart failure and stroke
  (responsible for 15-20% of total ischemic strokes)
- higher morbidity and mortality

AF CONSEQUENCES: AN OPEN QUESTION

- conflicting results in literature data
- oscillometric instruments do not work properly in AF
- AF usually arises with other concomitant pathologies
Physically-based multi-scale mathematical model (1)

GEOMETRICAL DOMAIN
(healthy young man)

Included elements
- left heart
- mitral and aortic valves
- 48 large/medium arteries
- 18 micro-circulation districts
- 24 arterial bifurcations

Excluded elements
- right heart
- venous return
- coronary and cerebral circulations
Physically-based multi-scale mathematical model (2)

EQUATIONS

Suitable lumped sub-models
- Left ventricle
- Mitral and aortic valves
- Micro-circulation districts

1D form of the mass and momentum balance equations
- Large/medium arteries

Conservation of total pressure and mass is set at
- Arterial junctions

NUMERICAL RESOLUTION
- Runge-Kutta Discontinuous-Galerkin scheme

CALIBRATION OF MODEL PARAMETERS
- normal hemodynamic results have to be reproduced as output
- a periodic heartbeat period of 0.8s is imposed
Fibrillated sequence of heartbeat periods (RR)

AF FEATURES CONCERNED
With respect to the Normal Sinus Rhythm (NSR)

- reduced temporal correlation
- increased temporal variability (higher standard deviation)

AF FEATURES NEGLECTED

- variation in mean heartbeat period/frequency in AF
PDF Characterization

Coefficient of Variation

\[ cv = \frac{\sigma}{\mu} \]

Extreme Values

IN NSR
A1 & A2 areas individuated by the 5th & 95th percentiles

IN AF
A1 increases up to A1’
A2 increases up to A2’
Result I: pressure fluctuations in AF

**cv VALUES**
- Systolic pressure: 7-8%
- Diastolic pressure: 14-19%
- Pulse pressure: 3-10%

Horizontal lines indicate the cv ratios in NSR and AF on aortic valve
Result II: extreme events are dramatically frequent in AF

- Percentile variations in AF (30 e 70) are constant along the arterial tree
- Similar results are found for diastolic and pulse pressures, as well as for flow rates
Pressure fluctuations; why?

Pressure signals are nothing but waves
- travel at a finite speed (waves speed or phase velocity)
- are reflected (especially at the arterial bifurcations)

TOTAL PRESSURE SIGNALS at a generic site B depend on:
1) pressure signals at A
2) the local phase velocity at B
3) how waves are reflected at C
4) distance to the nearest site of reflection BC

FLUCTUATIONS AROUND MEAN VALUES

Phase velocity: 6-18%
Magnitude of reflections: 4-29%
To Conclude...

MAIN RESULTS IN AF

- pressure fluctuations around mean values
- extreme pressures at each arterial section
- altered mechanisms which determine the local pressure signals

LIMITATIONS

- lack of a baroreflex regulation system
- absence of the coronary circulation

FUTURE IMPROVEMENTS/WORKS

- improving the actual mathematical model
- inquiring into the role played by the mean heartbeat frequency
- studying effects of pathologies such as hypertension
- entering the world of space medicine (AF during re-entry phase of spaceflights)
Thanks you for your attention!