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Pressure alterations along arterial tree during atrial fibrillation

AUTHORS

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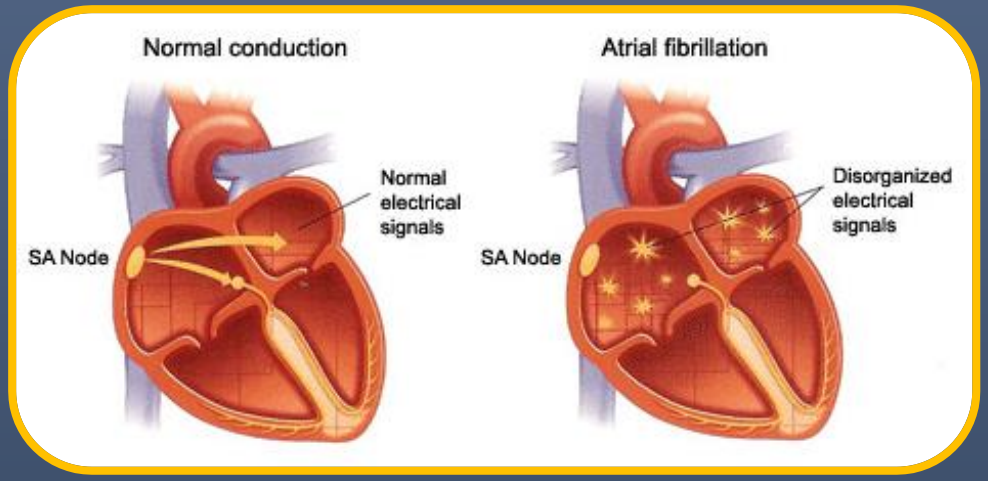
Atrial fibrillation (AF): the most common arrhythmia



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

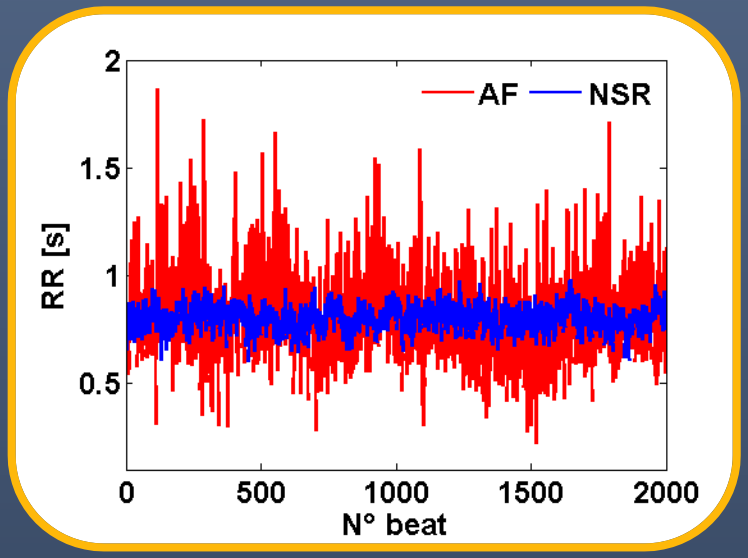
NUMERICAL RESOLUTION

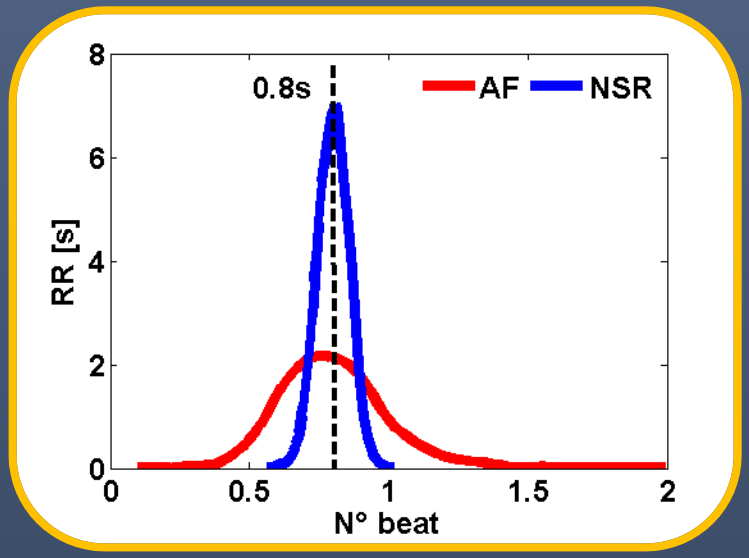
- Runge-Kutta Discontinuous-Galerkin scheme

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)





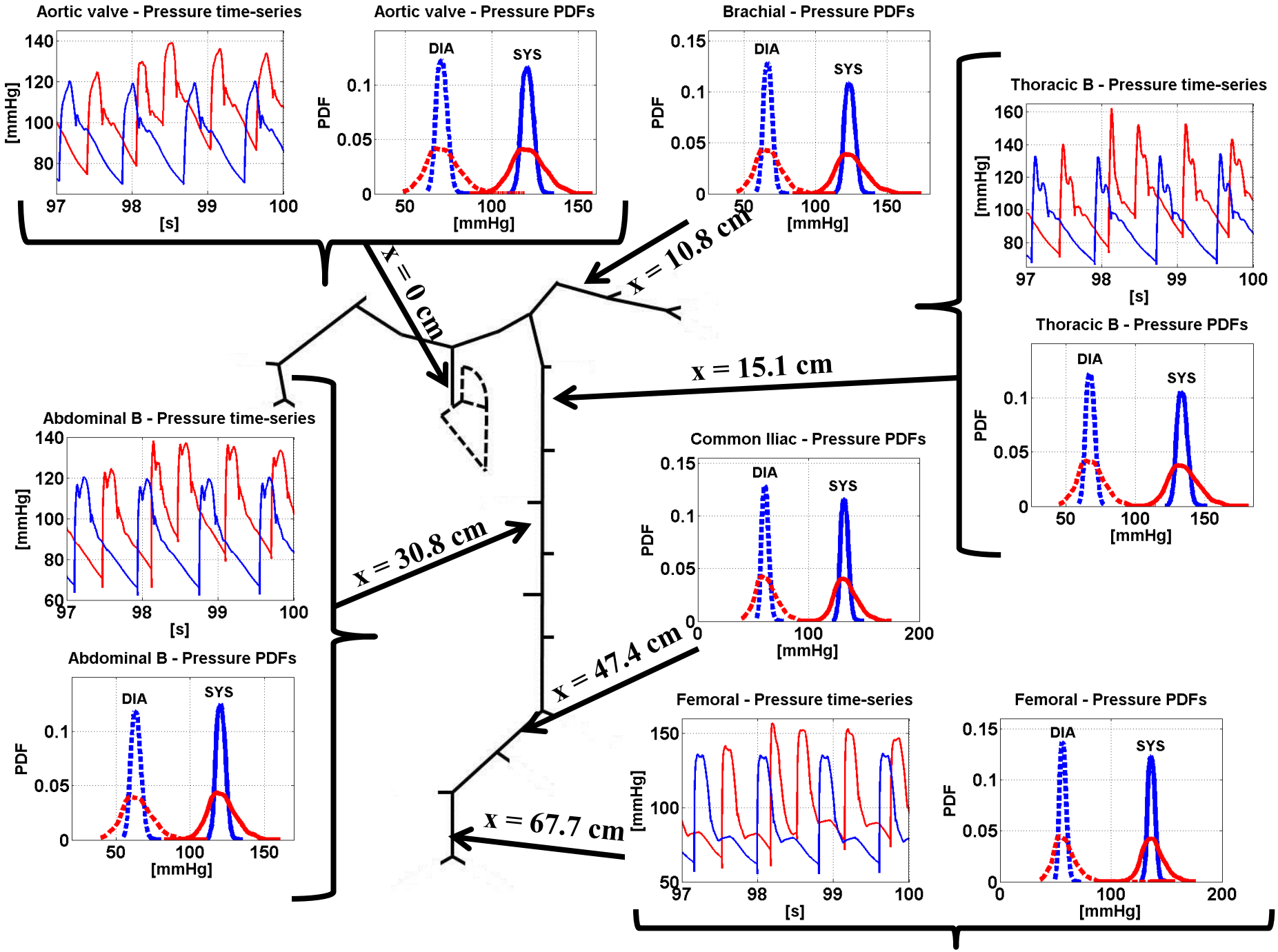
AF FEATURES CONCERNED

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**


Aortic valve - Pressure time-series
[mmHg]
[s]
Aortic valve - Pressure PDFs
DIA
SYS
PDF
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Brachial - Pressure PDFs
DIA
SYS
PDF
[mmHg]
x = 0 cm
x = 10.8 cm
x = 15.1 cm
Thoracic B - Pressure time-series
[mmHg]
[s]
Thoracic B - Pressure PDFs
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SYS
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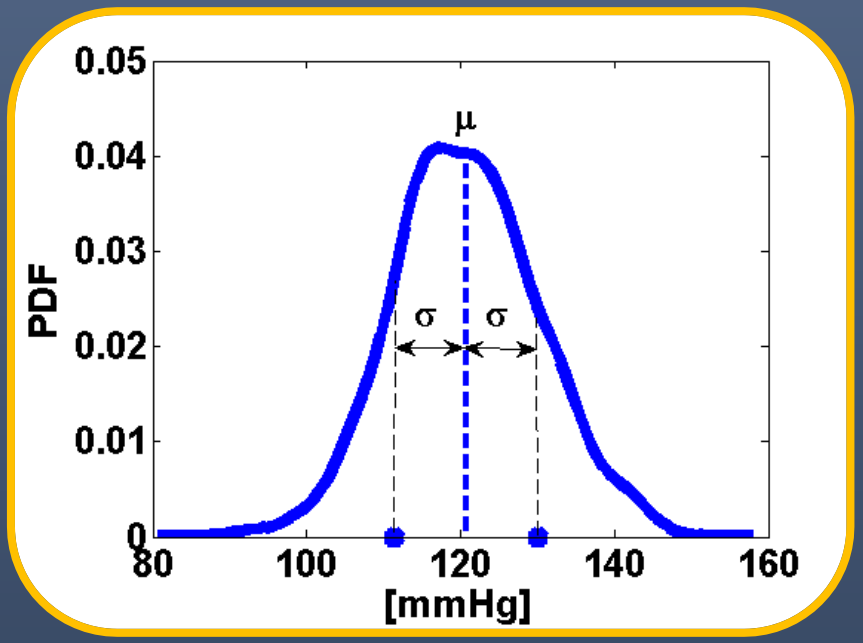
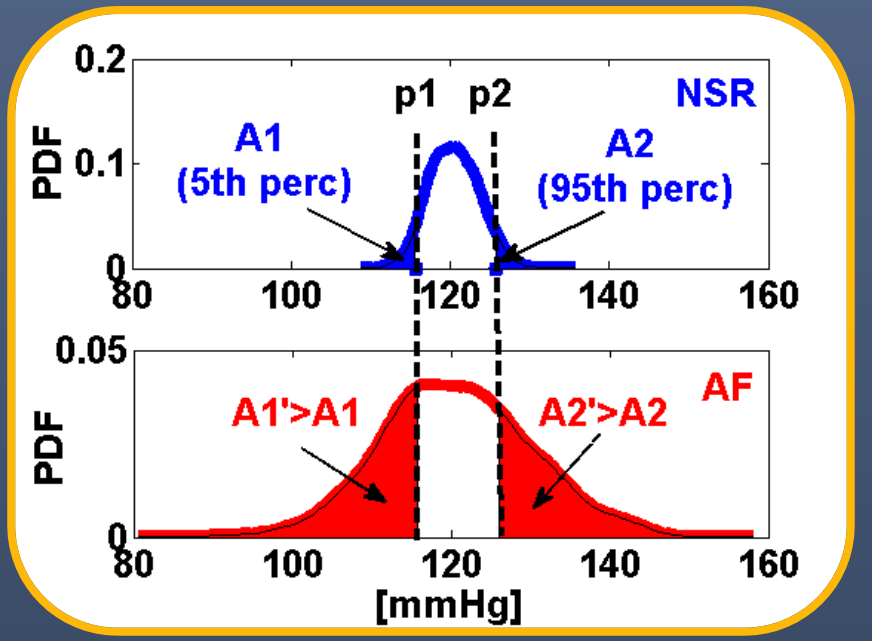
[mmHg]
Abdominal B - Pressure time-series
[mmHg]
[s]
x = 30.8 cm
Common Iliac - Pressure PDFs
DIA
SYS
PDF
[mmHg]
Abdominal B - Pressure PDFs
DIA
SYS
PDF
[mmHg]
x = 47.4 cm
Femoral - Pressure time-series
[mmHg]
[s]
x = 67.7 cm
Femoral - Pressure PDFs
DIA
SYS
PDF
[mmHg]

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'

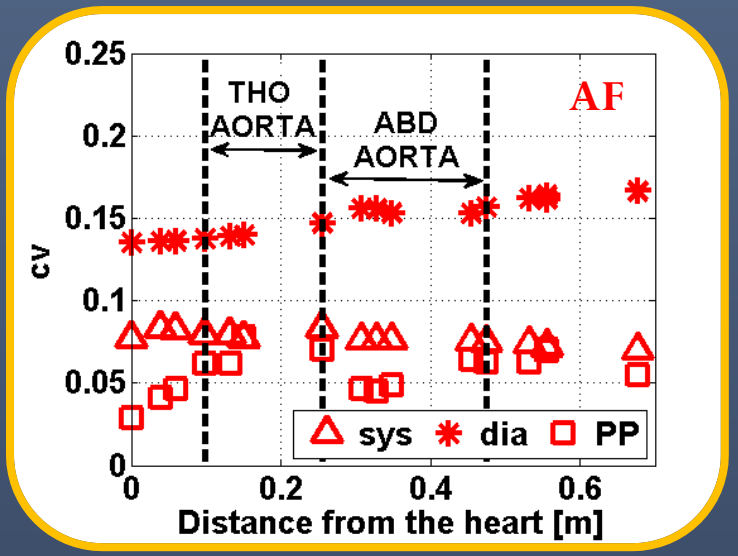
Result I: pressure fluctuations in AF

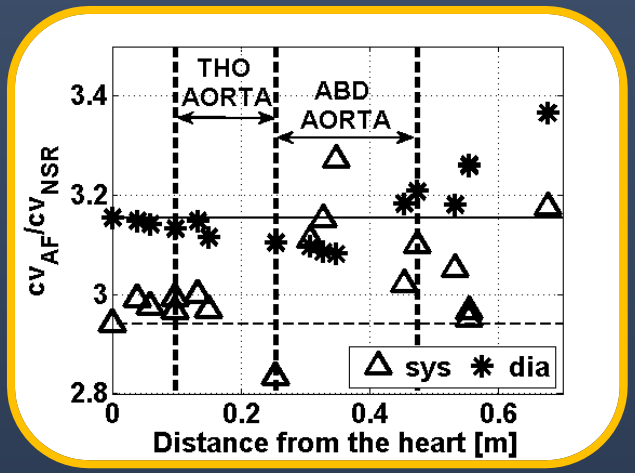
***cv* VALUES**

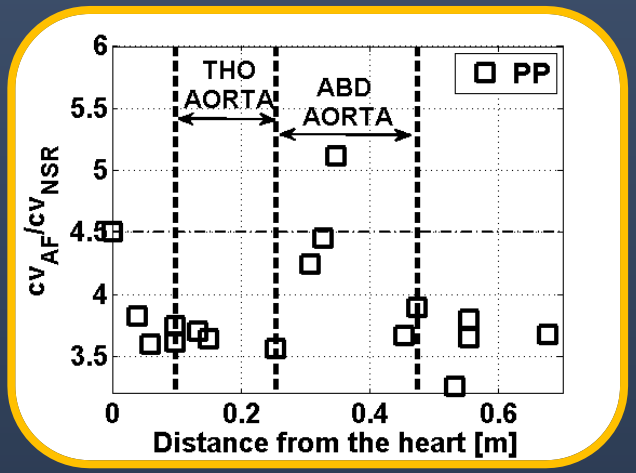
Systolic pressure: 7-8%

Diastolic pressure: 14-19%

Pulse pressure: 3-10%

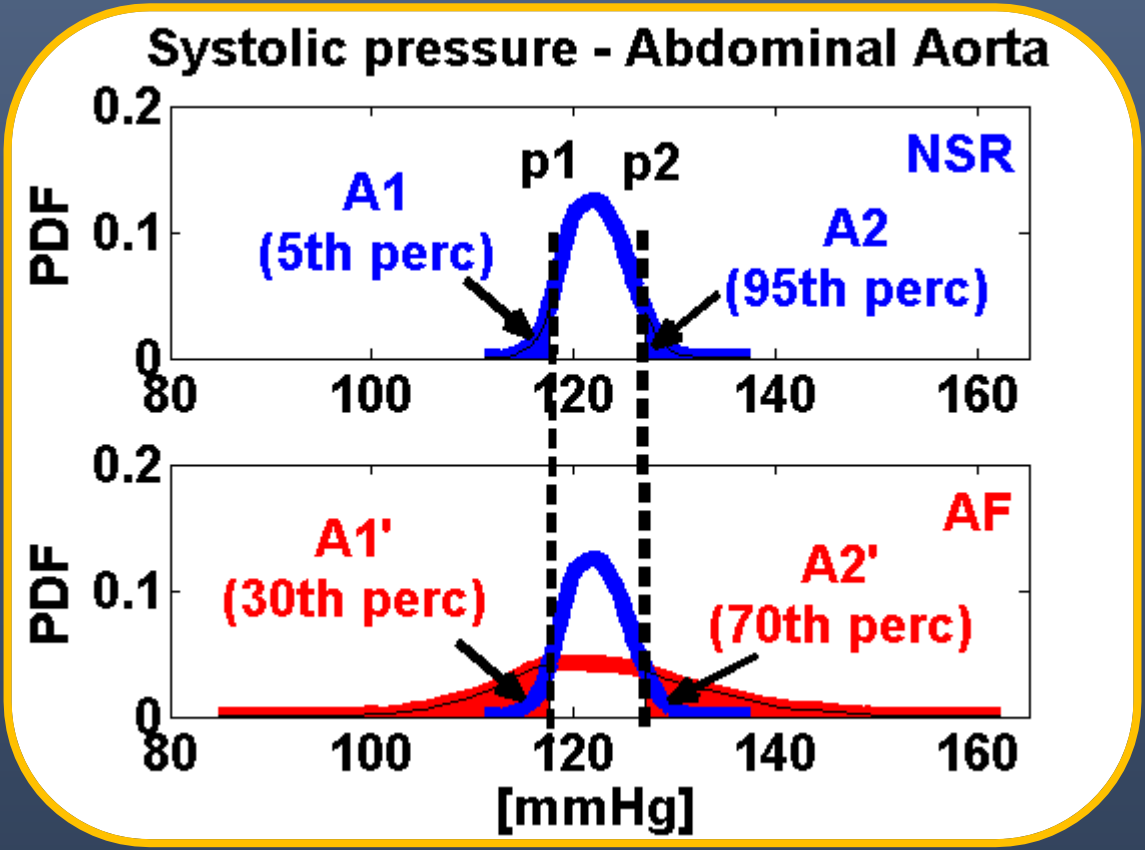






Horizontal lines indicate the *cv* ratios in NSR and AF on aortic valve

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?

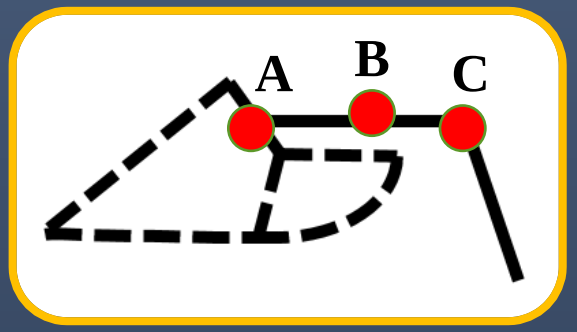
Pressure signals are nothing but <u>waves</u>

- **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

VARIABLE IN AF



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!