Patient-Specific Velocity Boundary Conditions from Phase Contrast Magnetic Resonance Imaging

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Supervisor: Simone Morganti, PhD
Outline

- Computational Fluid Analysis in the Biomedical Field
- Goal of the thesis
- From PC MRI data to patient-specific velocity profiles
- Conclusions and Future Works
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Computational Fluid Analysis (FSI/CFD) is:
- non-invasive
- potentially very accurate
- predictive

Therefore very useful in the Biomedical field
Computational Fluid Analysis (FSI/CFD)

A widely investigated issue for practical purposes:

- Gerbeau and Vidrascu, 2003 —> Algorithms for FSI
- Papaharilaou et al., 2006 —> FSI for Abdominal Aortic Walls Stress
- Bluestein et al., 2008 —> FSI for Abdominal Aortic Aneurysm
FSI/CFD Recipe

...What is needed?

Geometrical Domain

FSI/CFD

Inflow + Outflow
Geometrical Domain - Patient-Specific Approach

- Nealand and Kerckhoffs, 2009 —> Progress in Patient-Specific Approaches
- Auricchio et al., 2014 —> CFD for TEVAR evaluation
Aim of the thesis

Definition of a time and space-dependent Aortic Inflow using Patient-Specific Data from Phase Contrast Magnetic Resonance Imaging
Available Data - PC MRI

PC-MRI: physical principles

MAGNETIC FIELD
GRADIENT

subract these two to find motion-induced phase shift

Stationary spin

background phase shift

Moving spin

motion

Time

t0
t1
t2

background phase shift plus motion-induced phase shift
Two kinds of data

Unlike standard MRI, PC-MRI also employs information from phase maps.
Clinical Data

30 phase maps (ascending aorta slice) extracted via PC MRI at I.R.C.C.S. San Donato, Milan
Image Cropping and Segmentation

1) Rectangular, Automatic Cropping with ImageJ

2) Elliptical, Semi-Automatic Segmentation with Matlab
Once in Matlab, each image is related to a matrix, whose cells contain values in Hounsfield units (HU, from 0 to 255, measuring tissue density).
From Hounsfiel Units to Velocities

- In PC-MRI, mid-gray represents steady tissues ($H_{U0} = 127$)
- $H_{U{\text{max}}} = 255 \rightarrow$ MRI $V_{enc}$ (in this case, 200 cm/s)
- Being $R = V_{enc}/H_{U{\text{max}}}$, we can use the following relation:

$$v(i,j) = (H_{U}(i,j)-H_{U0})R$$
Comparing Datasets

Our Data vs Machine-provided Data

In blue, our plot representing mean velocity vs time, compared to the data provided by I.R.C.C.S. San Donato (in red)
Results

mean velocity vs time

space-dependent velocity profiles

A

B

C

D

(cm/s)

(ms)

A

B

C

D

cm/s
Conclusions

In the present work:

- literature review on computational fluid analysis
- collection of patient-specific PC MRI data
- elaboration of the provided data to obtain time- and space-dependant velocity profiles

Obtained patient-specific aortic inflow from PC MRI is in good agreement with machine-provided data
Future Work: Data interpolation

- Data are represented on a finer grid (but still discrete!)
- We would need an interpolant function $\rightarrow$ (LIFE V)
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