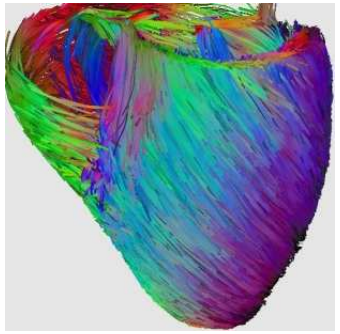
Creatis

Imagerie du Vivant– 11 Dec 2012



Three-Dimension Fiber Architecture of the Human Heart *In Vivo*

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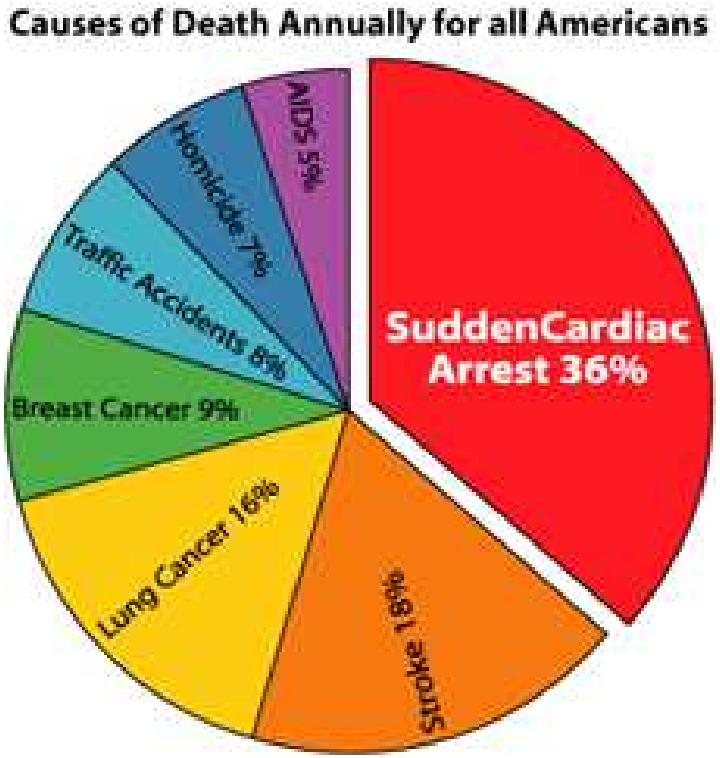
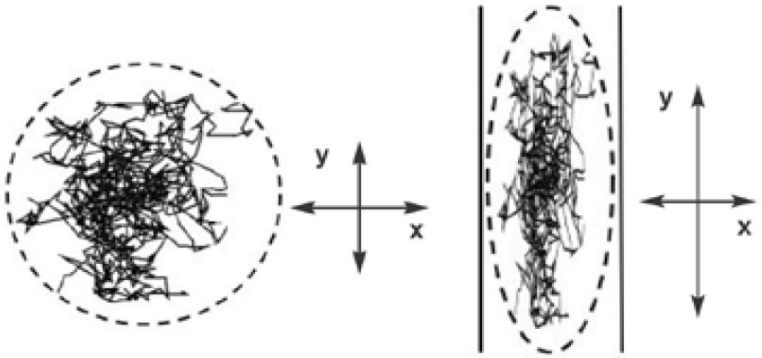
Why we study the heart fiber structure?



- According to the survey of 2011, the heart disease is mainly responsible for the death of people.
- The cardiac fiber structure plays an important role in ensuring normal functions of the heart.
- In order to discover these diseases as early as possible, we need to understand the relation between disease and heart fiber structure .

Fig1. The pie chart for the causes of death in 2011
http://www.tiptoptens.com/2011/01/12/top-10-leading-causes-of-death-in-the-world-2010-2011/

Motivation

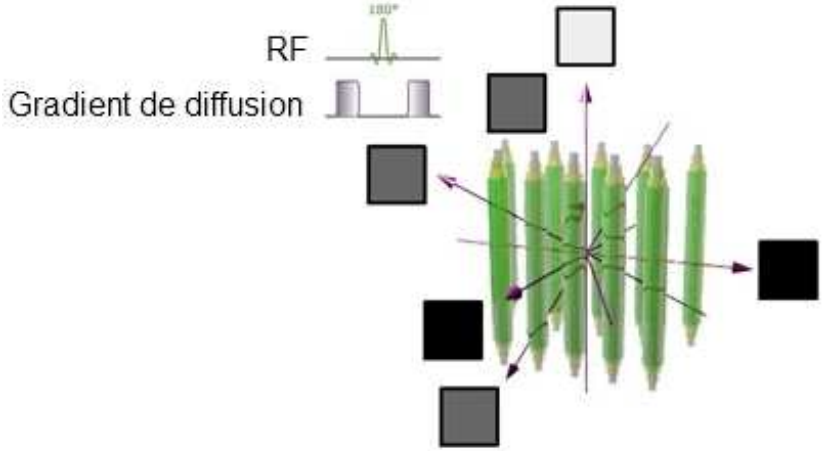


Unrestricted Tissue boundaries

Water molecules diffusion without (left) and with (right) restriction.

- The displacement of water molecules can reflect the microstructures of the human heart.

Principle of DTI

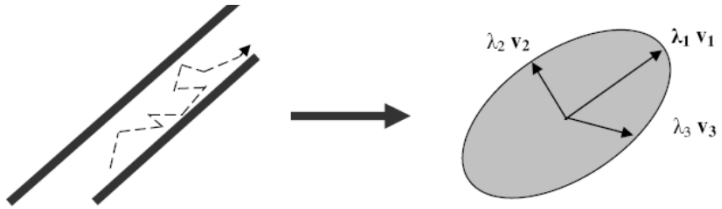


$$SI = S_0 \cdot e^{-bD}$$

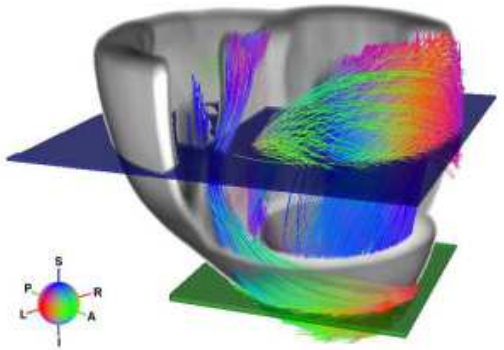
(Stejskal, 1965)

Diffusion coefficient

$$D = \begin{bmatrix} D_{xx} & D_{yx} & D_{zx} \\ D_{xy} & D_{yy} & D_{zy} \\ D_{xz} & D_{yz} & D_{zz} \end{bmatrix} \qquad D_{prin} = \begin{bmatrix} \lambda_1 & 0 & 0 \\ 0 & \lambda_2 & 0 \\ 0 & 0 & \lambda_3 \end{bmatrix}$$



Simulated fibers and the ellipoide representing the diffusion



Fiber tracking

Why DTI is difficult to obtain in the heart *in vivo?*

- D~10^{-3}mm/s. Heart volecity 0~5cm/s. Heart motion much higher than D! the measurment of D is not easy.

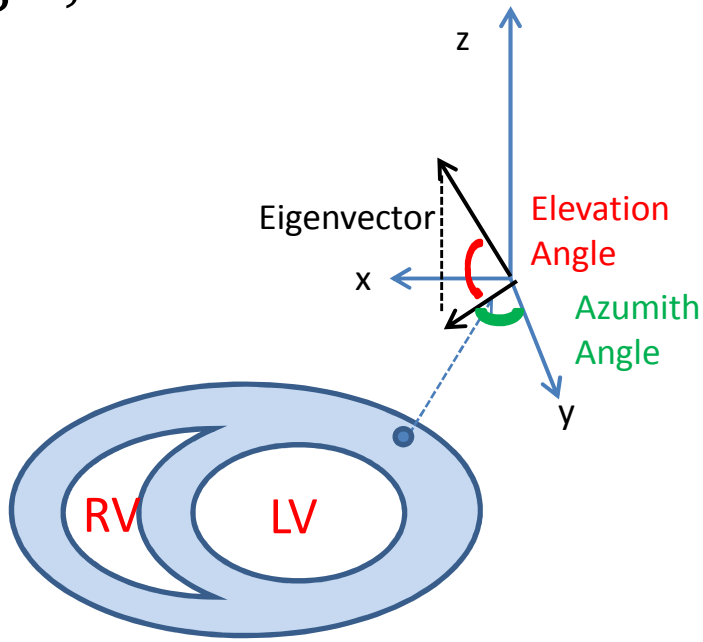
- Large signal loss in diffusion weighted (DW) images due to physiological motion (cardiac and breathing motion) are superimposed on top of the DW images.

Objective

- To obtain *in vivo* cardiac fiber architecture of the human heart in free-breathing conditions

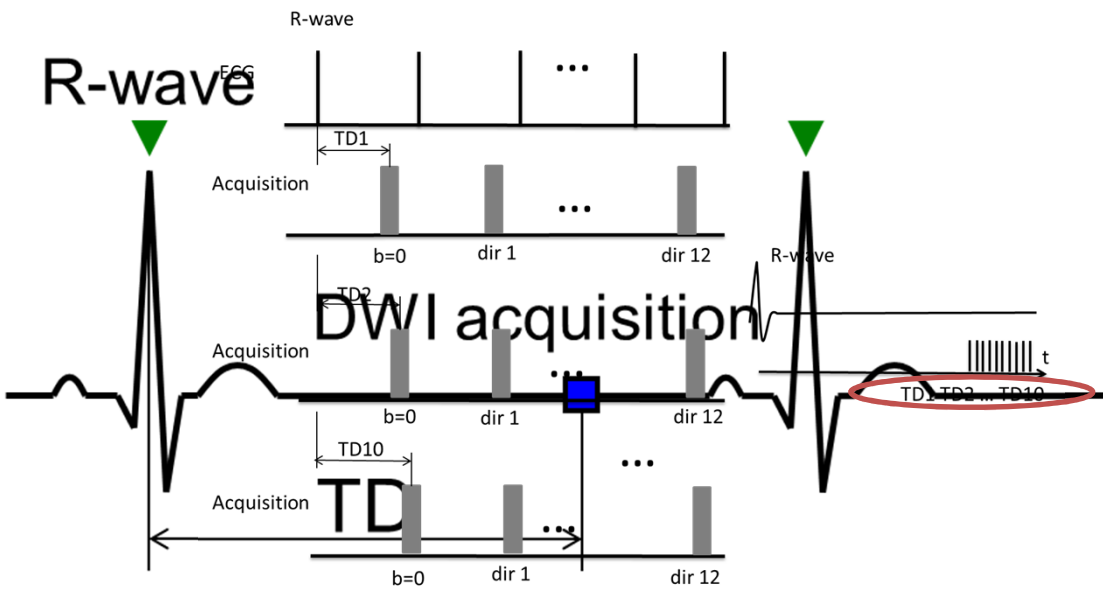
Image analysis & Assesment of fiber architecture properties

We calculate fractional anisotropy (FA), mean diffusivity (MD), fiber angle, tensor field and 3D fiber architecture



Determination of fiber helix angle

MRI acquisition



Trigger delay (TD) was chosen to be optimized diastolic time-point.

In vivo acquisition scheme

b = 200 s/mm²
TE/TR = 51/100 ms,
Resolution = 2.6 x 2.6 x 6 mm,
acceleration rate = 2 (GRAPPA),
partial Fourier = 6/8,
Matrix = 90x160,

10 DT-MRI slices across the whole heart.

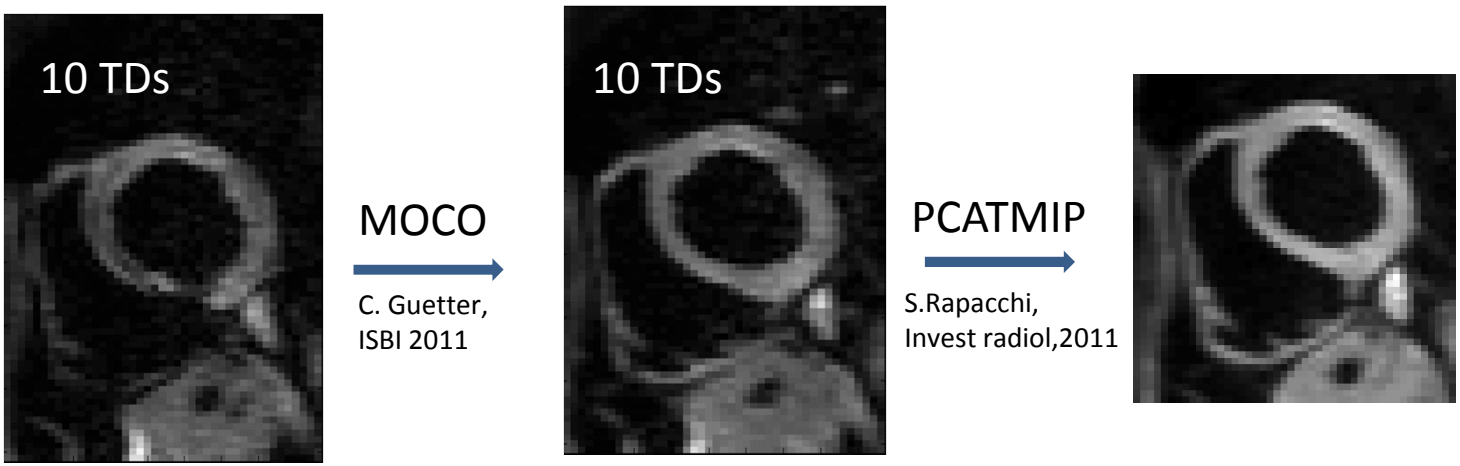
Scan time: (12 direction+b0) × 10 Trigger delay × 10 slices = 1300 R-R ~25 mins

In vivo cardiac DTI with FB: Post-processing

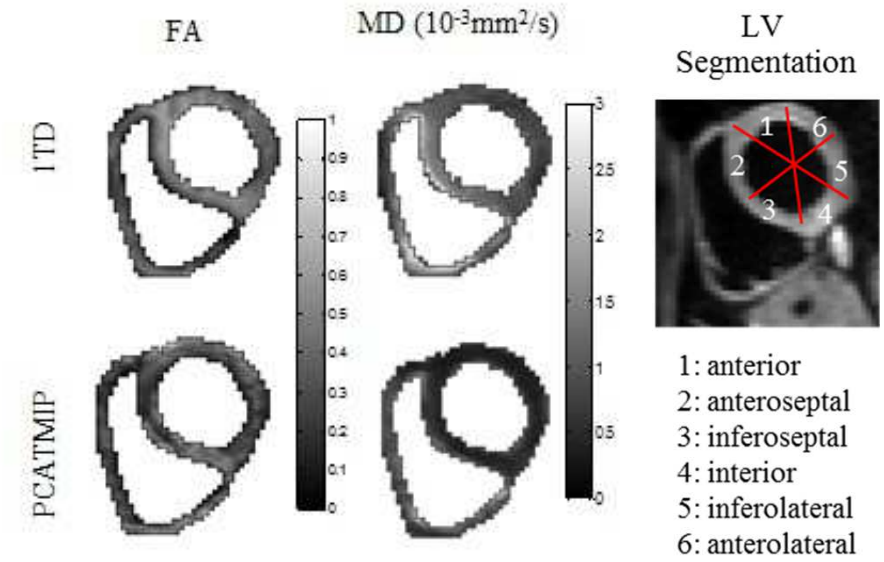
Physiological Motion

Respiratory motion: image registration
(MOCO, C. Guetter, ISBI 2011)

Cardiac motion: PCA+tMIP
(PCATMIP, S.Rapacchi, Invest radiol,2011)

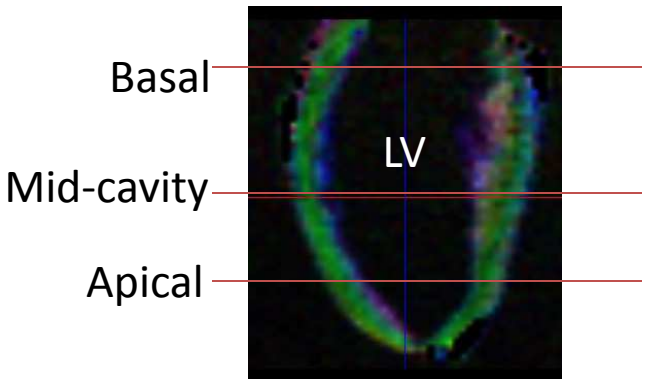


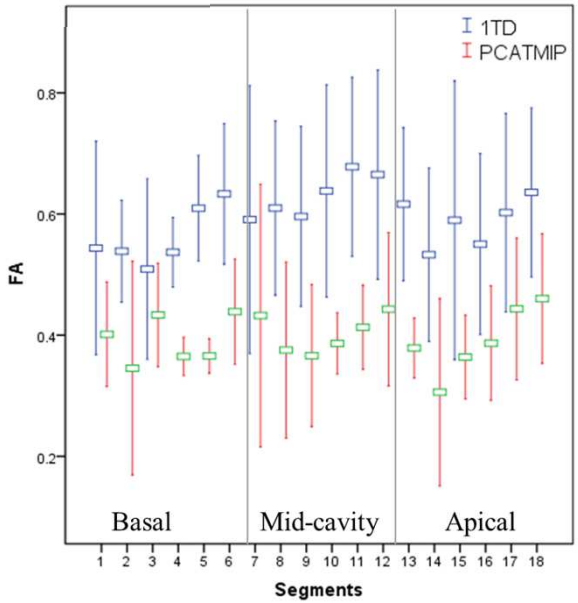
In vivo cardiac DTI with FB: Results

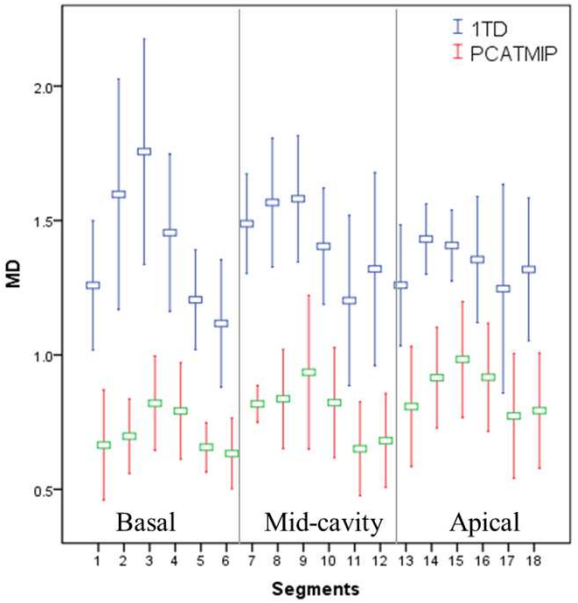


1: anterior
2: anteroseptal
3: inferoseptal
4: interior
5: inferolateral
6: anterolateral

In vivo cardiac DTI parameters and LV segmentation







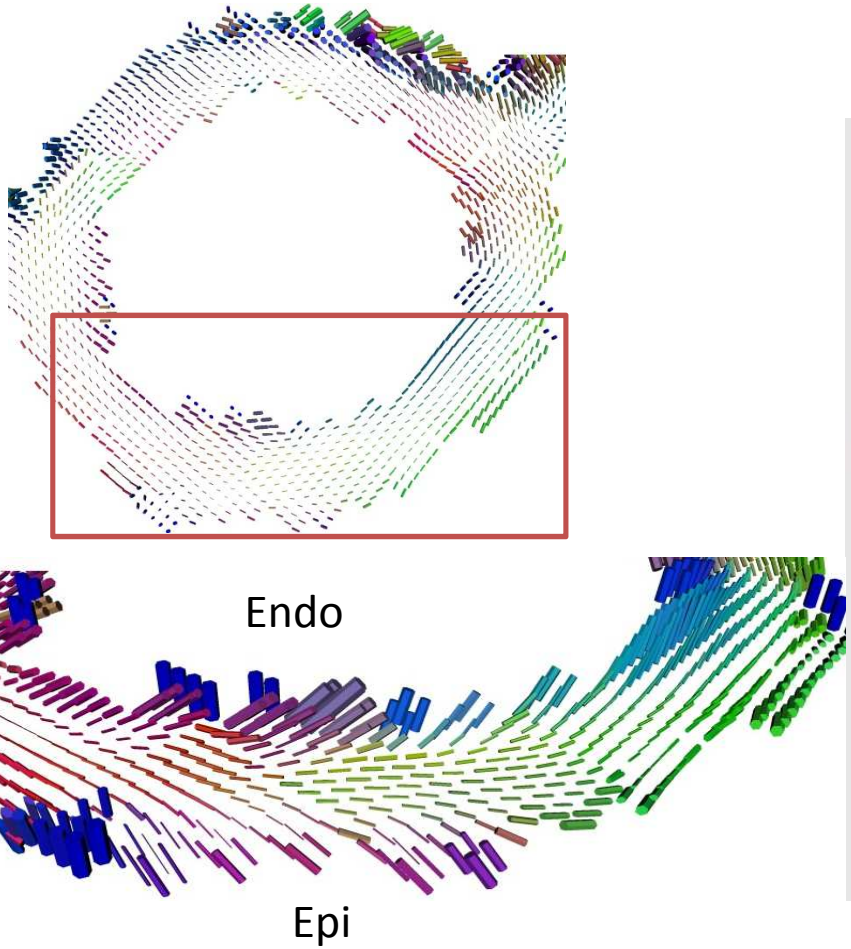
In vivo cardiac DTI parameters in different segments (mean ± SD)

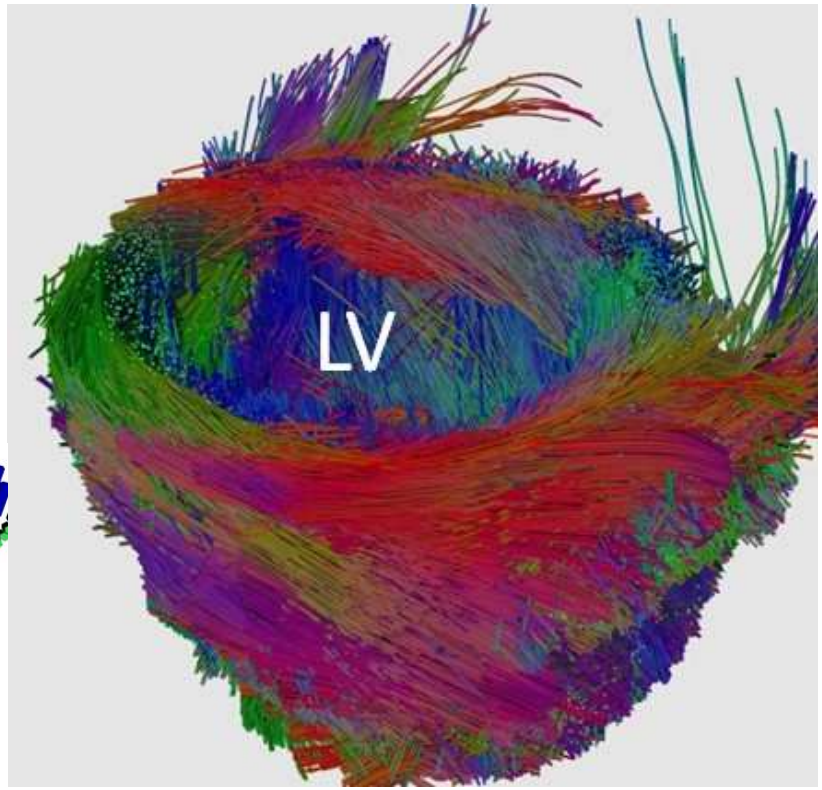
In vivo cardiac DTI: Results

		Basal	Mid-cavity	Apical
FA	1TD	0.56±0.16	0.63±0.17	0.59±0.15
	PCATMIP	0.39±0.09	0.40±0.1	0.39±0.08
MD	1TD	1.40±0.37	1.43±0.28	1.34±0.24
	PCATMIP	0.75±0.16	0.79±0.20	0.87±0.21

Mean ± SD FA and MD values of the LV over 6 volunteers. MD values are in units of $10^{-3}mm^2/s$.

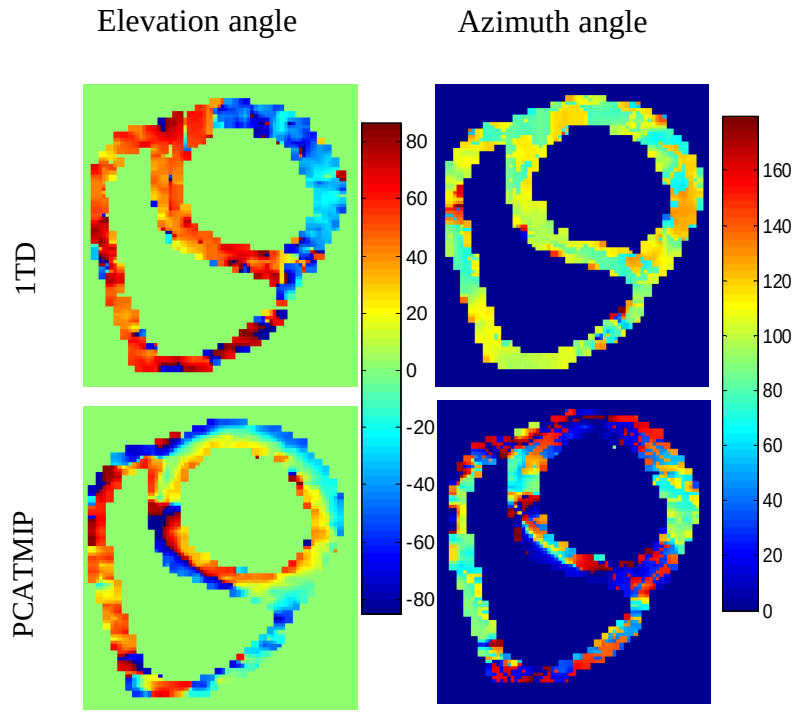
In vivo cardiac DTI with FB: Results

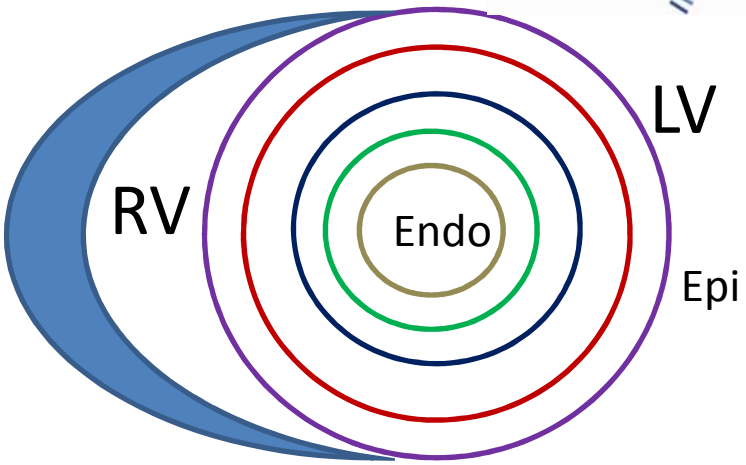




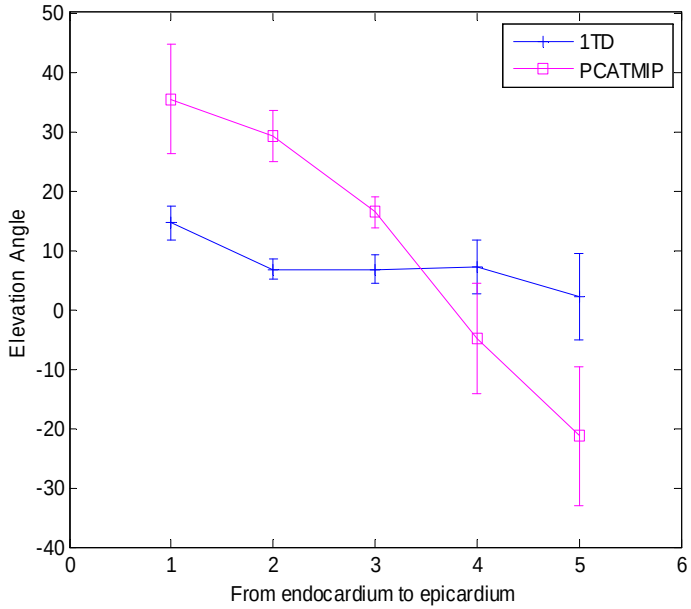
In vivo 3D fiber architecture of a volunteer, obtained after interpolating the tensor field derived from PCATMIP method.

In vivo cardiac DTI with FB: Results





the LV wall segmentation



Conclusions

- The combined use of registration and PCATMIP allows us to obtain *in vivo* 3D fiber architecture of the human heart with free-breathing.

Perspectives

- Enhancement of diffusion signals in *in vivo* cardiac DTI through exploiting temporal frames

- Faster acquisition and try to obtain multi-phase tractographies...

Thanks for your attention