Quantification of Right Ventricular Function in Pulmonary Hypertension using Cardiac PET Images

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Motivation and Goals

Motivation:

- 3 year survival 48% without treatment and 55% with current therapy.

Long term goal:

- To understand the risk factors and causes of pulmonary hypertension (PH), understand disease progression, and develop therapies.

Immediate goal:

- Develop an automatic tool with optional operator intervention for defining RV region of interest in 3D cardiac images:
  - Used to quantify RV cardiac function.
  - Used to quantify RV molecular function.

http://www-sop.inria.fr/asclepios/projects/Health-e-Child/DiseaseModels/content/cardiac/tofSimu1_introduction.php

Normal RV

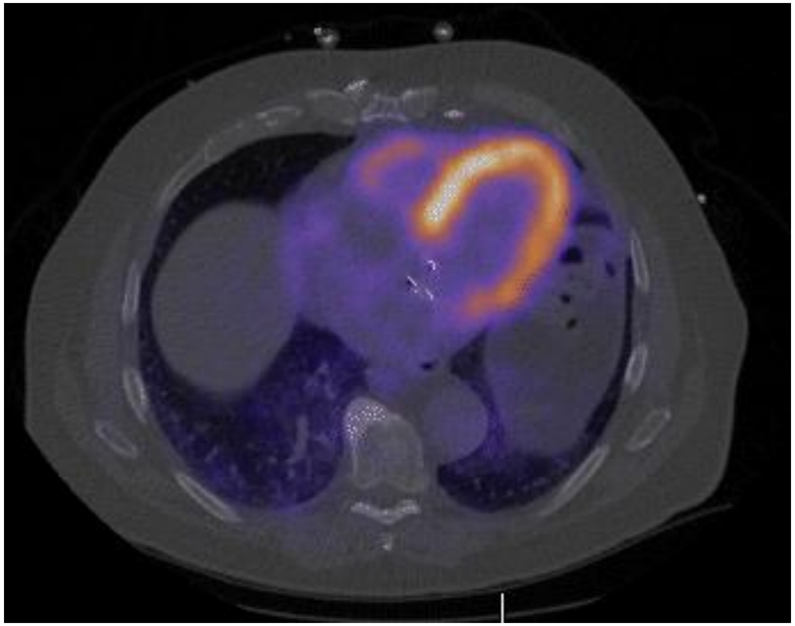
Introduction – Literature Review

- Advanced PH is associated with RV hypertrophy and dysfunction. [1,2]
- Previous work investigated use of SPECT for imaging advanced disease. [1,2,4]
  - Limited understanding of PH and its relation to RV function.
  - Manual segmentation of the RV.
- Early RV disease may be better <u>detected</u> and <u>understood</u> with SPECT and PET imaging. [1]
  - Perfusion?
  - Metabolism?
- Automatic quantification of left ventricular (LV) function using FlowQuant. [3]
  - RV function not currently measured for PET images.

[1] Pereira, *JNM* 1997:38(2);254.
[2] Naeije, *European Heart Journal Supplements*, vol. 9, no. suppl H, p. H5, 2007
[3] Klein, *Nuclear Science Symposium Conference Record, 2006*.
[4] Mannting, JNM, vol. 40, no. 6, pp. 889–894, Jun. 1999.

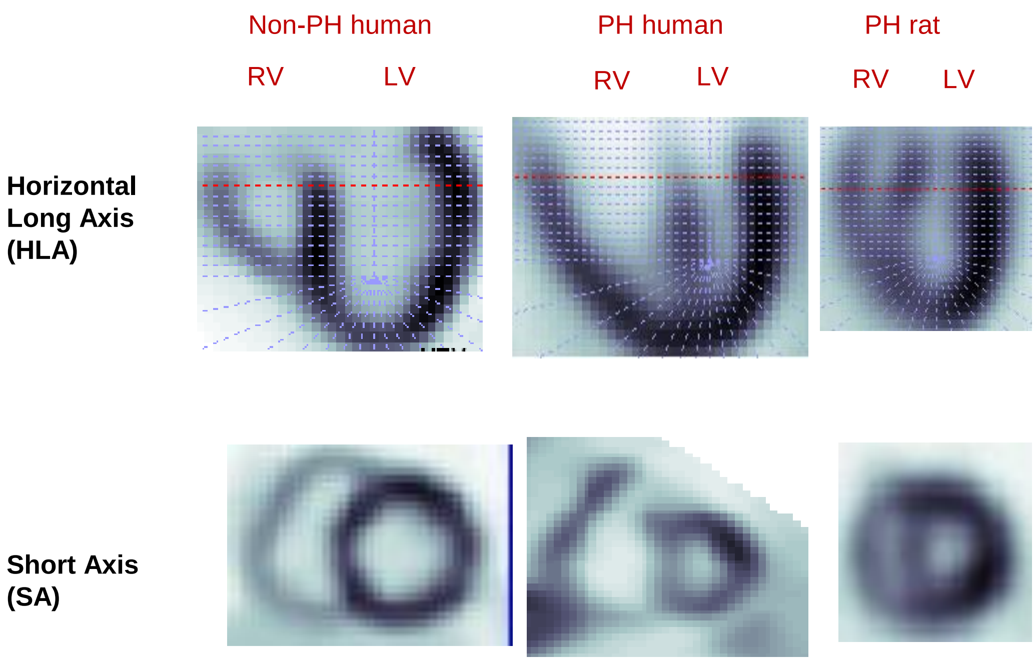
Brief Overview of PET and SPECT

- Injected tracer – trace amounts of specific molecule that interacts physiologically.
- Specialized camera detect radiation and reconstruct 3D image **volume** of tracer concentrations.

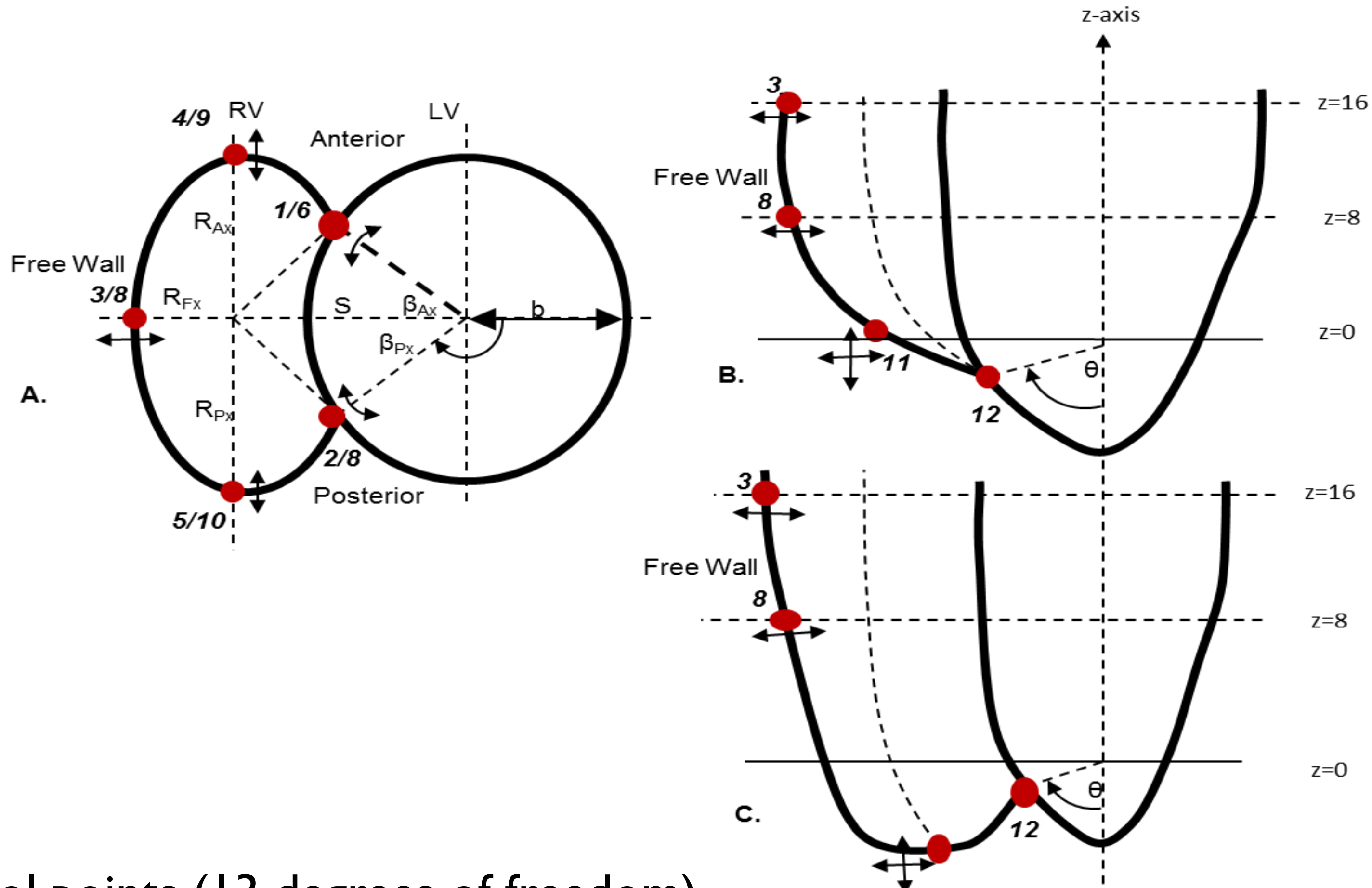


Introduction – Model properties

- Automatically register RV ROI with optional operator intervention:
  - Accommodate all RV anatomies (normal, hypertrophic)
  - Minimum control points and degrees of freedom

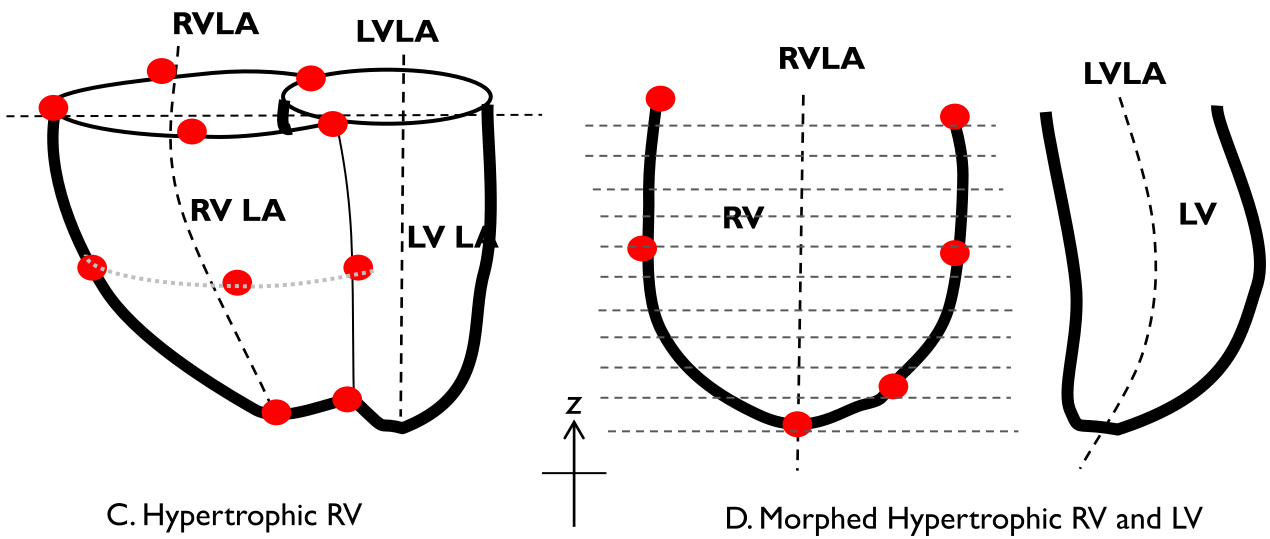


Defining Model Shape



- 12 control points (13 degrees of freedom).
  - Initially estimated based on LV shape.
  - Automatically optimized
  - Adjustable by operator (GUI)

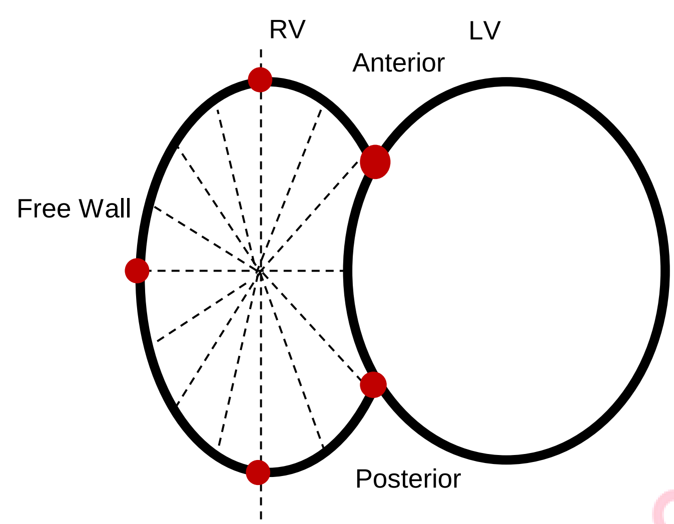
Defining Model Shape - Interpolation



C. Hypertrophic RV

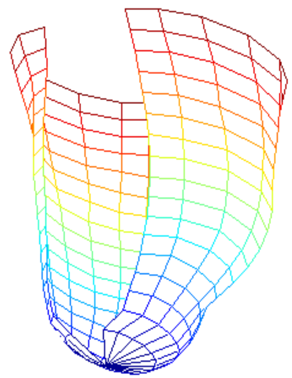
D. Morphed Hypertrophic RV and LV

- Sampling points interpolated in pseudo-cylindrical coordinate system:
  - 16 slices by18 sectors = 288 sampling points.
  - *Radii* interpolated for each *slice* and *sector.*

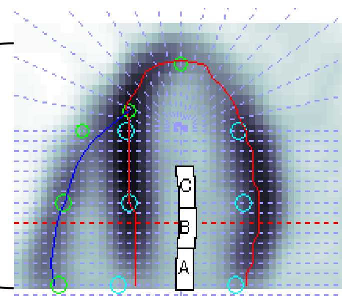


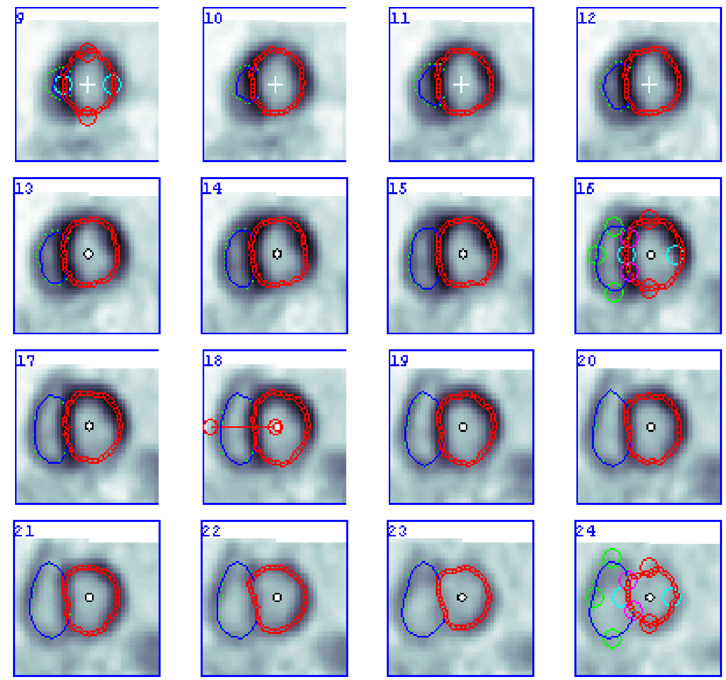
Graphical Representation

3D Mesh



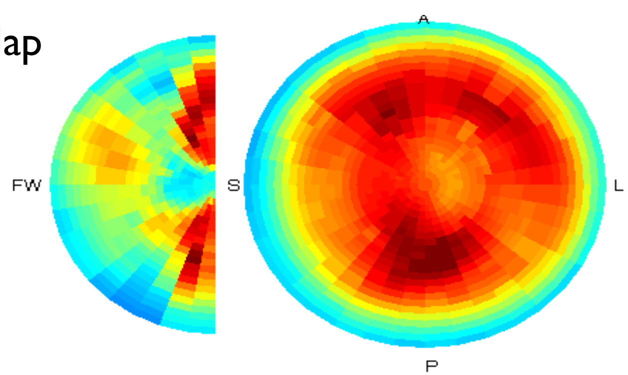
Horizontal Long Axis (HLA) slice



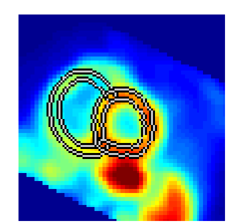


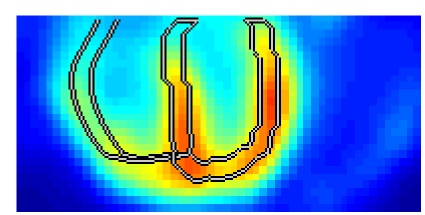
Short axis (SA) slices

Polar Map



RV LV

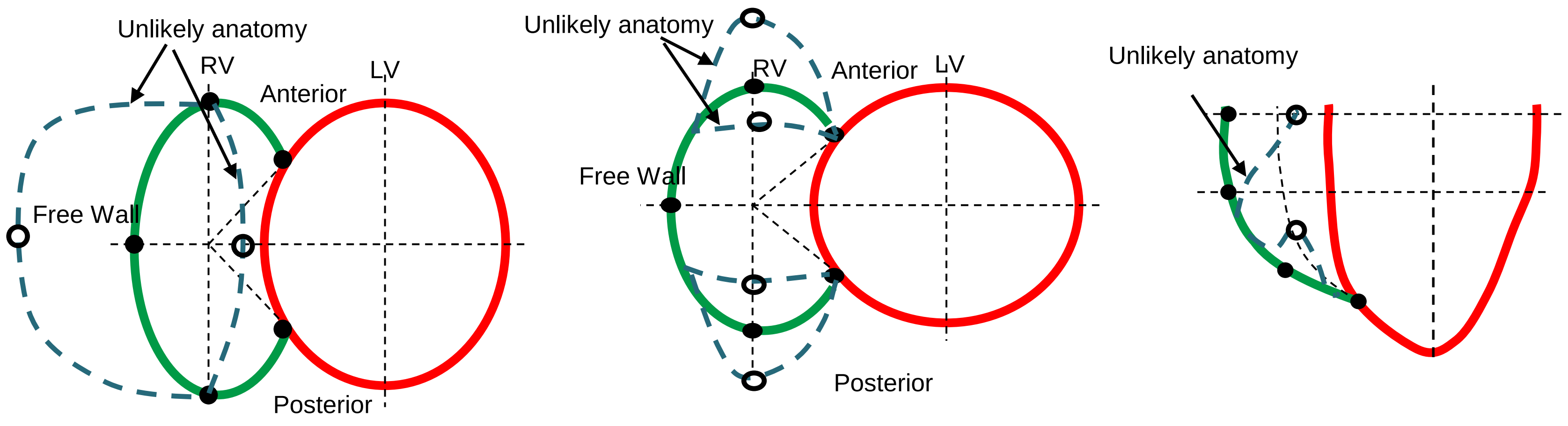




Global Contour Optimization

- Minimization of a cost function
  - $C = C_{intensity} + C_{constraints}$
- Maximization of sampled image intensity
  - $C_{intensity} = \sum_{p \in ROI} \frac{I_{max}}{I_{max} - I_p}$

    where I_{max} is the maximum image intensity and I_p is the image intensity of pixel p
- Constraints on RV shape and size



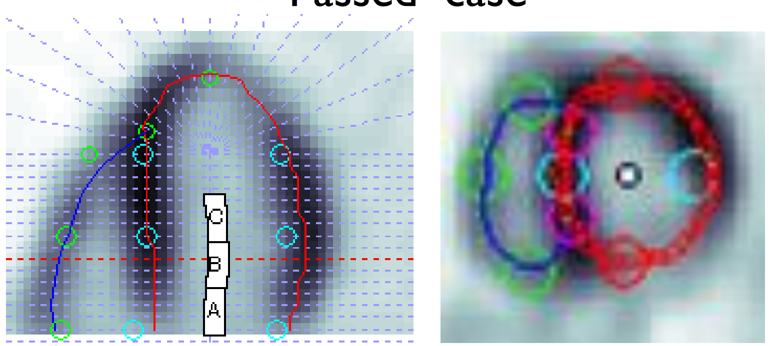
Model Validation and Characterization

- Model Appropriateness
  - Manual adjustment of control points
- Automation Performance
- Operator Dependent Variability
  - 2 operators x 2 runs each
  - Tracer uptake reproducibility
  - Sampling point position variability
- Cavity Volume and EF Accuracy (PET vs. CMR)

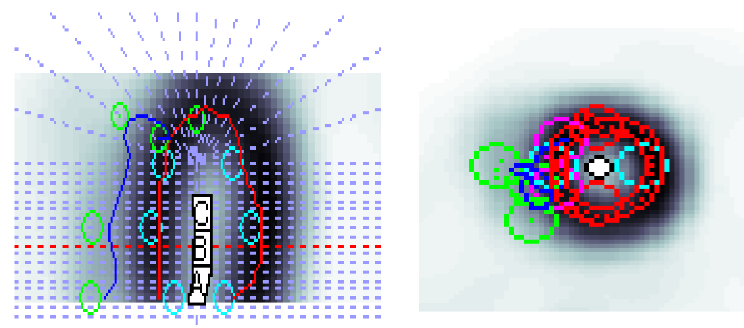
Model Validation-Results

- Model appropriateness - 20 Images (5 non-PH, 5 PH, 5 normal rat, 5 PH rats*)
  - 14 passed, 6 failed
  - Low image intensity in normal rats
- Automation performance - 14 Images that passed model evaluations:
  - 7 complete automation
  - 13 successful automatic fitting of the free wall

Passed case

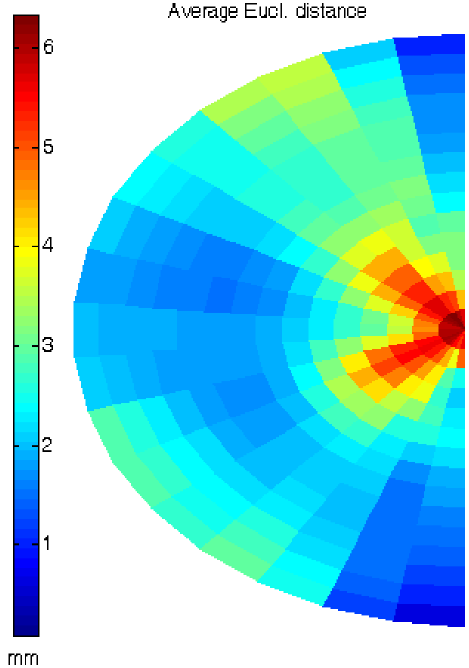


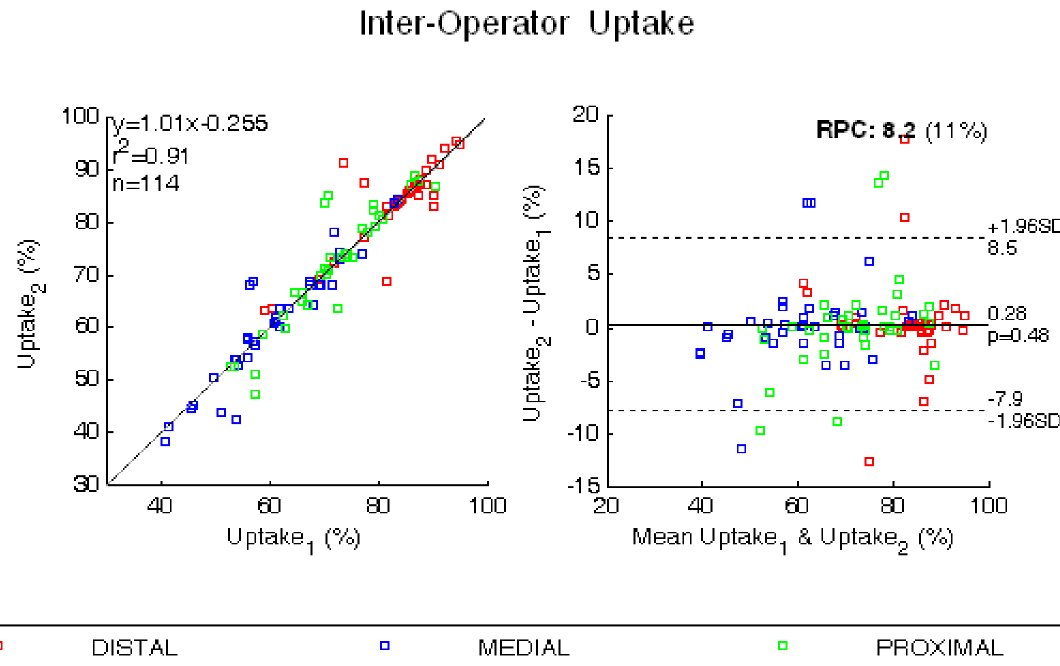
Failed case



* PH induced by treating with monocrolatine (MCT)

Model Validation - Operator Variability



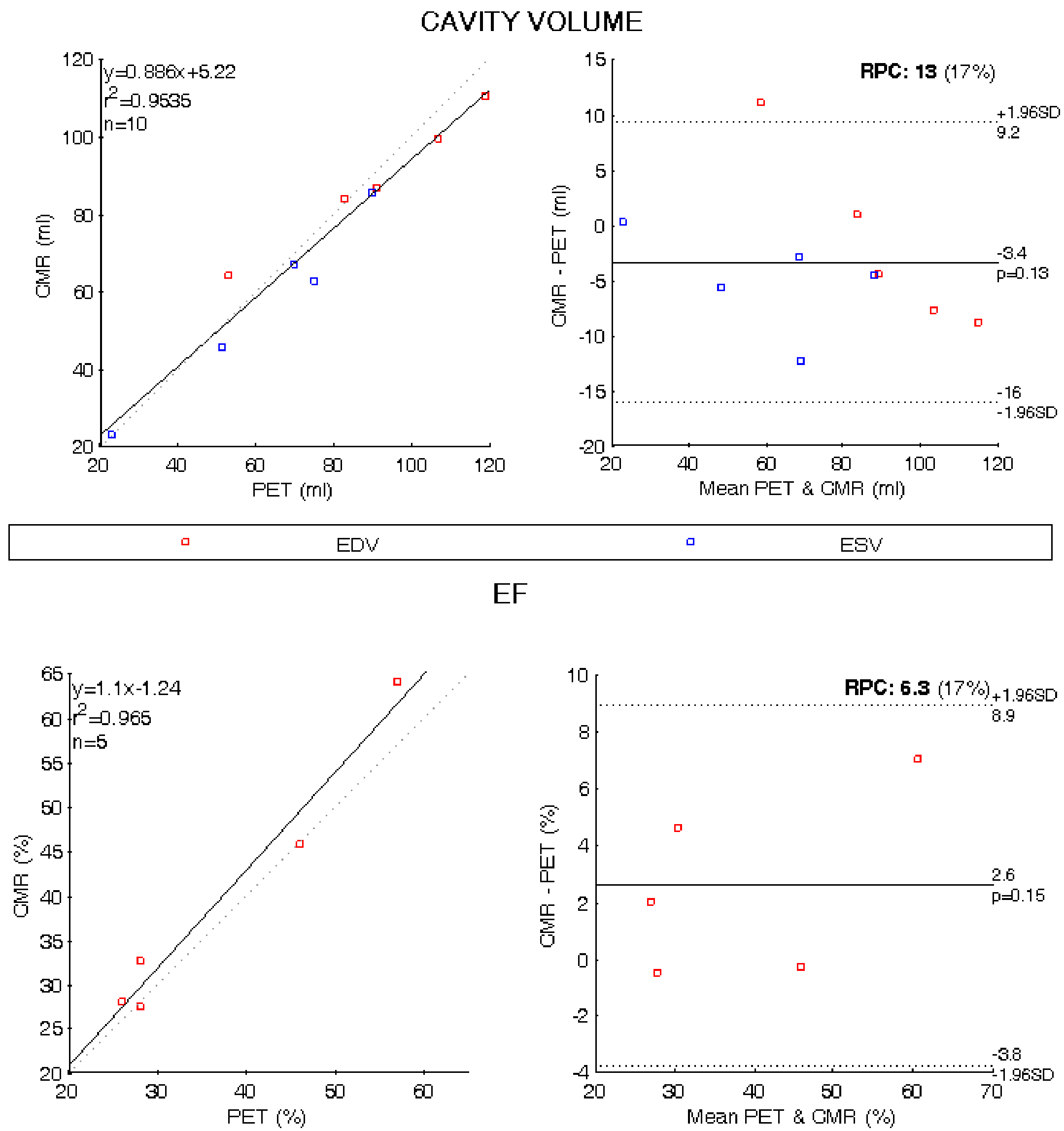


- 2 operators
  - Expert and Novice
- 2 runs each:
  - separate days
  - anonymized
  - Randomized order

		RV (current)	**LV** (Klein et-al)
		RPC	RPC
Intra Operator	Op 1 (expert)	5.6	0.97
Variability	Op 2 (novice)	6.4	1.2
Inter Operator Variability		8.2	1.8

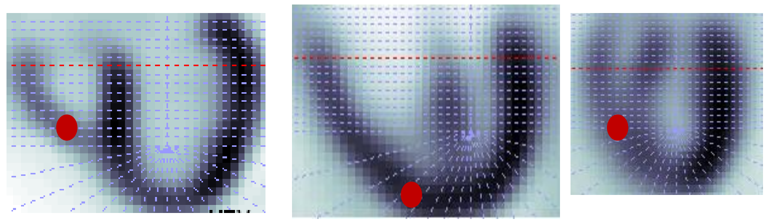
Cavity volume and EF accuracy-Results

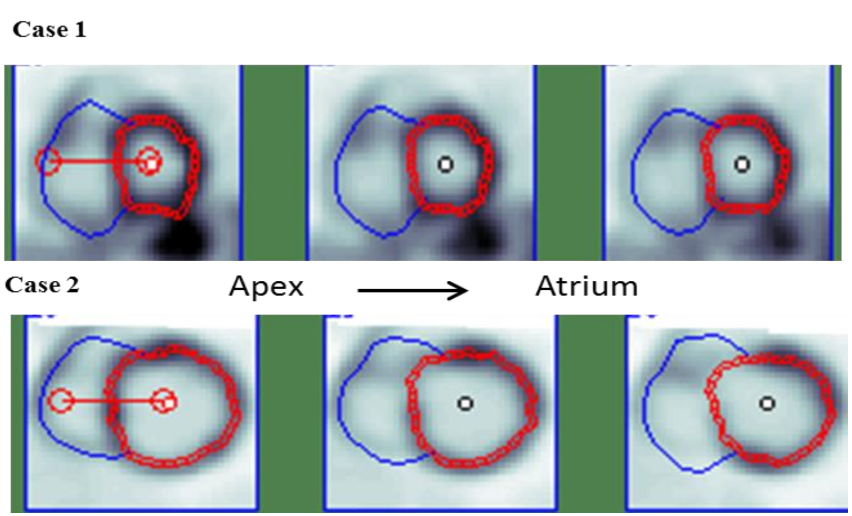
- (PET vs. CMR)

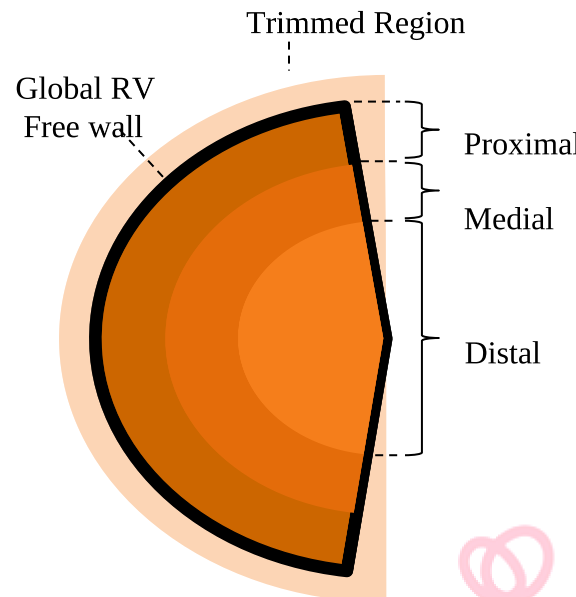


Results Summary

- Complete automation not achieved due to:
  - Image Intensity (low around the atrium)
  - Spillover from LV
  - A wide range of RV anatomies
  - RV bifurcation into PA and RA
- Nevertheless, semi-automated tool can be used for current research.







Discussion and Limitations

- Operator reproducibility
  - Did not include animal images.
  - Limited demographics.
- Cardiac function accuracy (PET vs. CMR)
  - Small number of patients.
  - Limited demographics.
- Only used ^{18}F labeled tracers.
  - Lower quality images not included.
  - Did not include SPECT image.

Conclusions

- Developed, validated, characterized, and demonstrated a spline model that sufficiently registers the RV region of interest semi-automatically.
  - First of its kind
  - Sufficient for current and future research of PH in animal models and clinical studies.
- Future Work
  - Improve Automation
  - More Validation
  - Development and evaluation of kinetic modeling for quantification of physiologic function.

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