

Mathematical modelling in physiology: biomedical applications
Moscow, 21-24, March 2016

Importance of Translational Biomedical Modelling Research - Pathways to impact

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Acknowledgements: Igor Efimov, Yuri Vassilevski, Igor Sazonov, Etienne Boileau



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Current Membership Biomedical Engineering Group

Professors

P. Nithiarasu (cardiovascular and respiratory flows)
M.F. Webster (Rheology)

Associate Professors

M. Ellero (microfluidics)
R Ransing (prosthetic mechanics)
R van loon (valves, cardiovascular and lymphatics)

Senior Lecturers/Lecturers/Research Fellows

A. Aggarwal (biology and solid mechanics)
I. Sazonov (preprocessing and patient-specific modelling)
C. Wang (micro and nanoscale biomechanics)

We are recruiting!

(1) New Lecturer/Senior Lecturer/Associate Professor
(2) Rising star



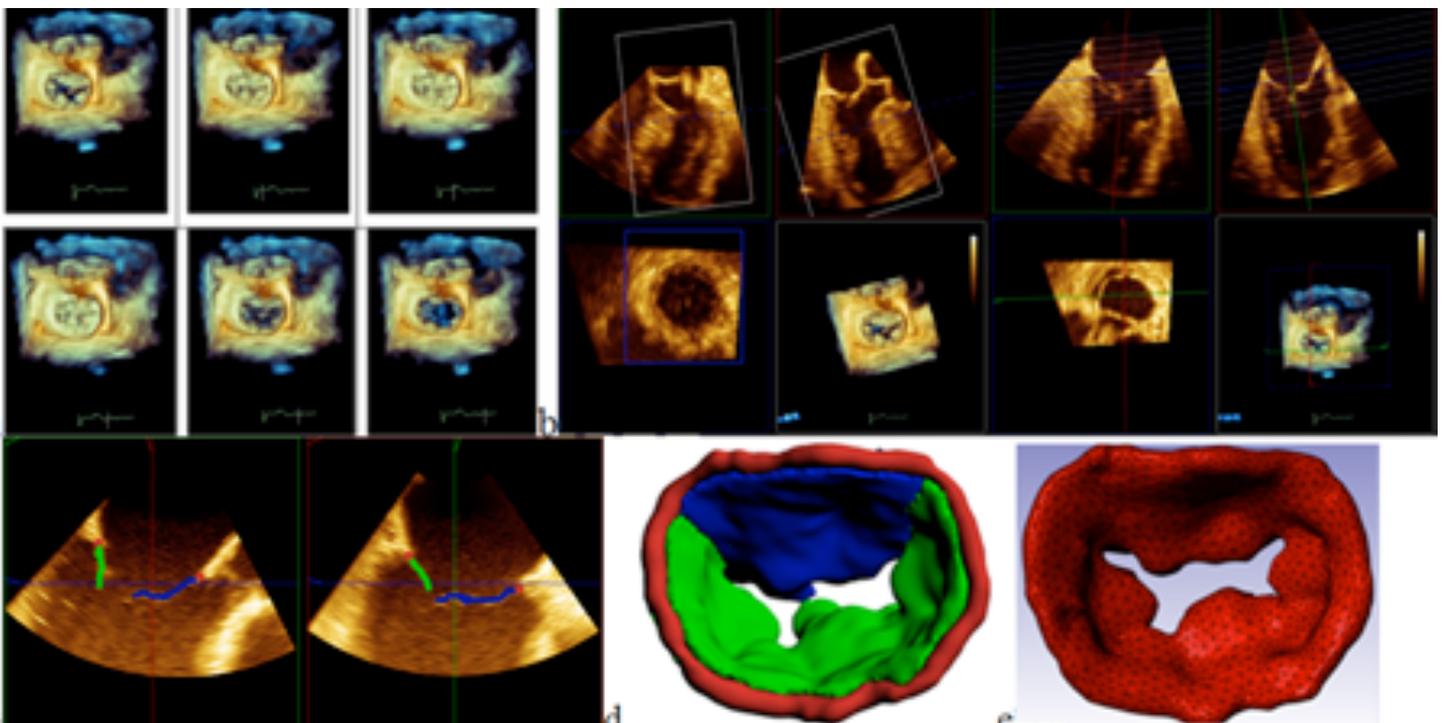
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Clinical Thinking - Mitral Valve Example



Hossien, Nithiarasu, et al., *European Journal of Cardiothoracic Surgery*, 2015.



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Contents

- Curiosity driven research - long term. 
- Targeted research - short and medium term. 
- How is targeted research designed/developed? 
- What can we do to improve translation? 
- Comparison between engineering and Bio CFD. 

Winner of the Ig® Nobel Prize

FLUID DYNAMICS: Victor Benno Meyer-Rochow of International University Bremen, Germany and the University of Oulu, Finland; and Jozsef Gal of Loránd Eötvös University, Hungary, **for using basic principles of physics to calculate the pressure that builds up inside a penguin, as detailed in their report "Pressures Produced When Penguins Pooh -- Calculations on Avian Defaecation."**

PUBLISHED IN: Polar Biology, vol. 27, 2003, pp. 56-8.

Source: <http://www.improbable.com/ig/winners/>



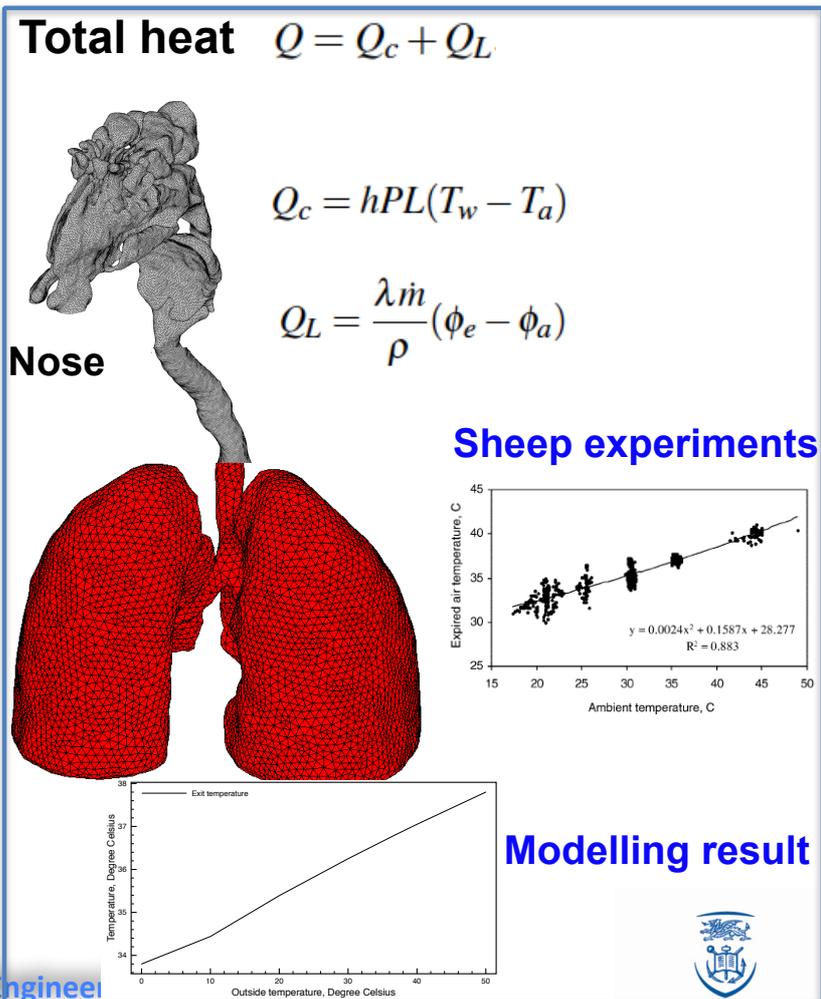
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How do we do research?

Curiosity driven research - No clear and immediate pathways to impact

Heat transfer in respiratory systems



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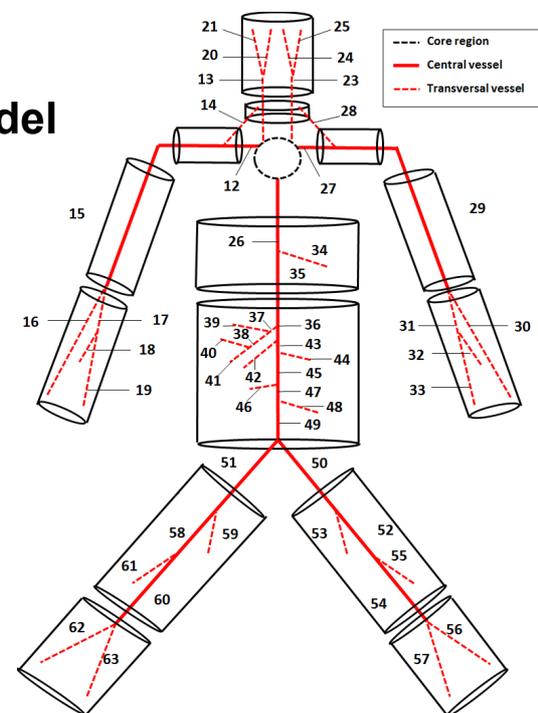
A segmented model that includes convective transport

More Curiosity driven research

Objectives:

- Develop a model that combines segmented heat conduction model with systemic circulation model.
- Study hypothermia and determine the temperature distribution with time and space.

Bioheat transfer model



Alberto Coccarelli's work



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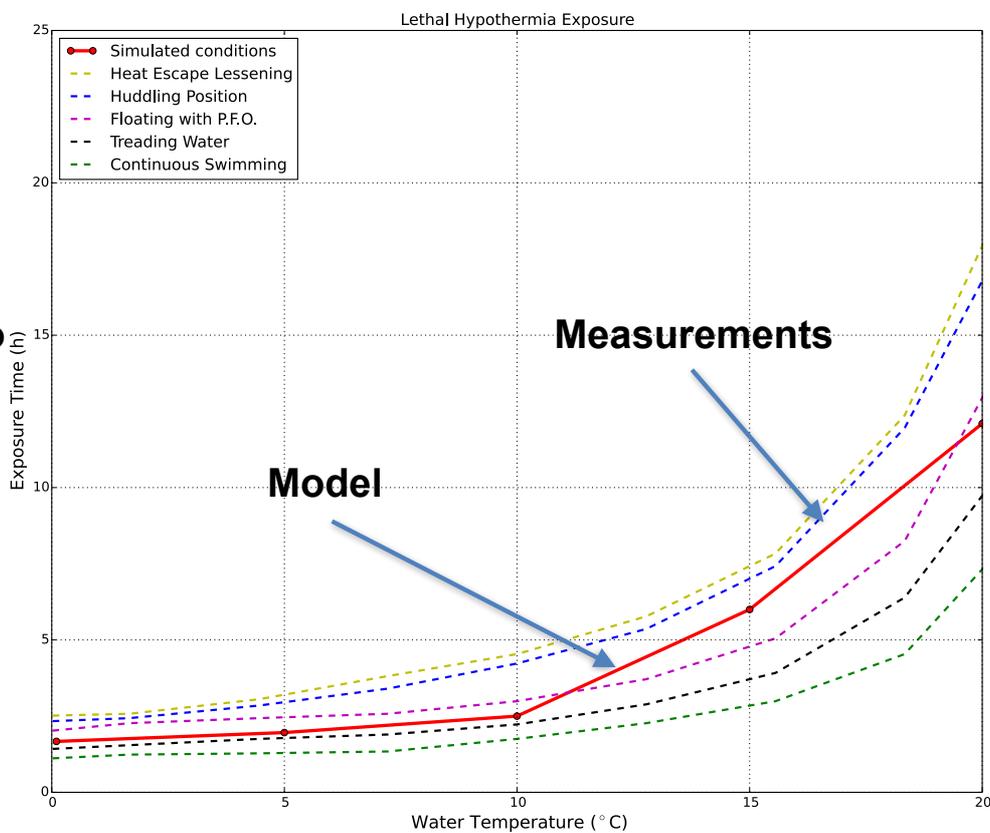
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Results - Different cold exposure conditions

More Curiosity driven research - bioheat transfer



Critical time to develop hypothermia

Model

Measurements



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Alberto Coccarelli's work

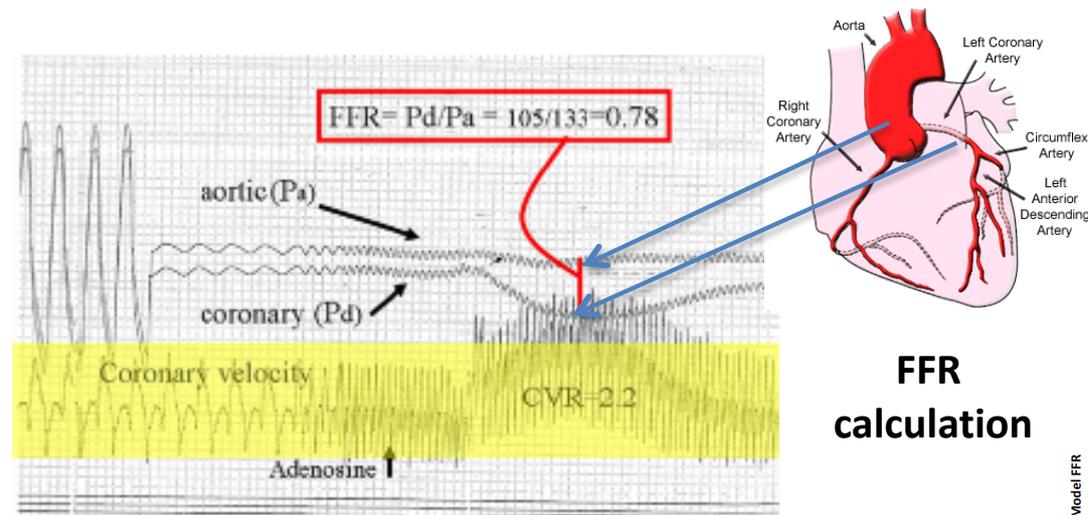
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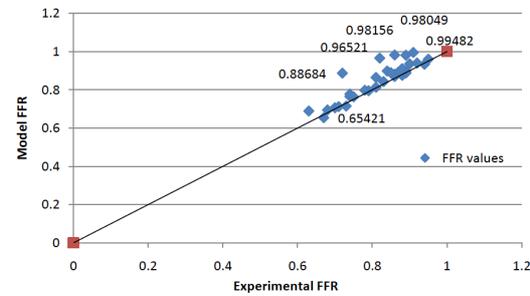
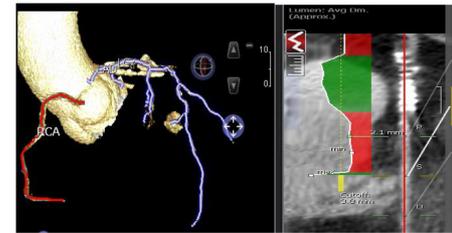
How do we do research?

Targeted research with **short and medium term impact**

Modelling Fractional flow reserve



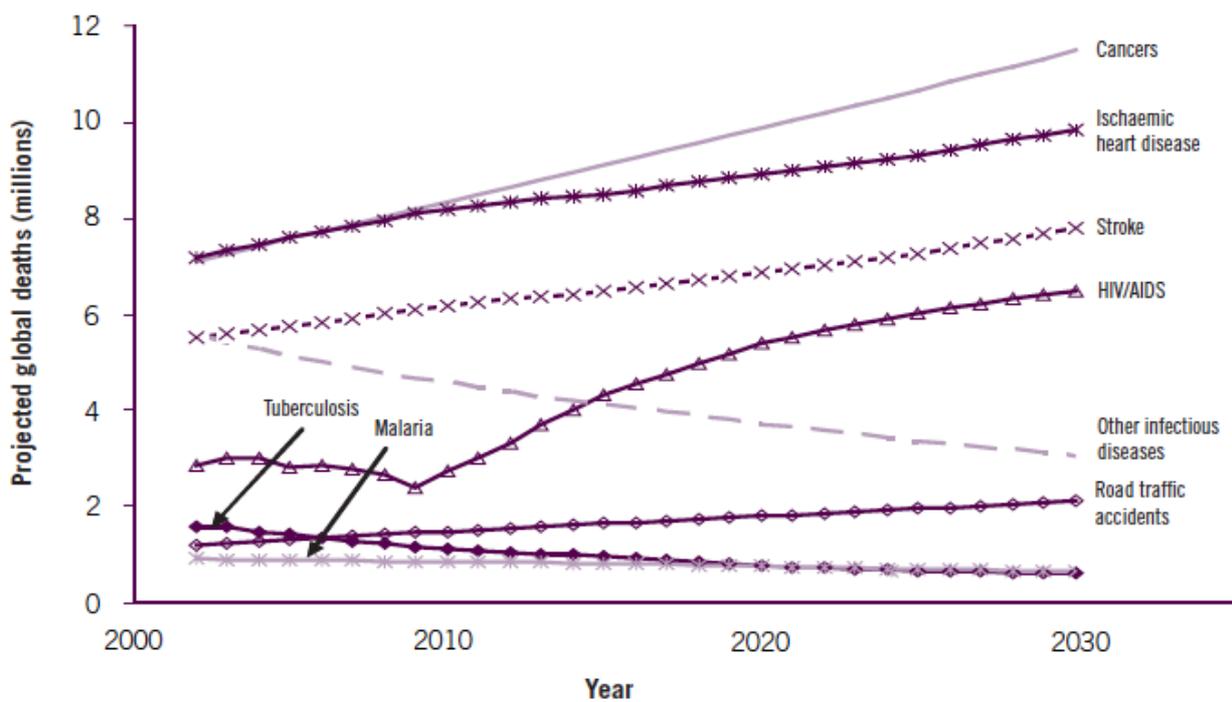
FFR calculation



Kern and Samady, Journal of American College of Cardiology, 2010.

Why targeted research?

Projected global deaths for selected causes of death, 2002–2030¹⁵



WHO report



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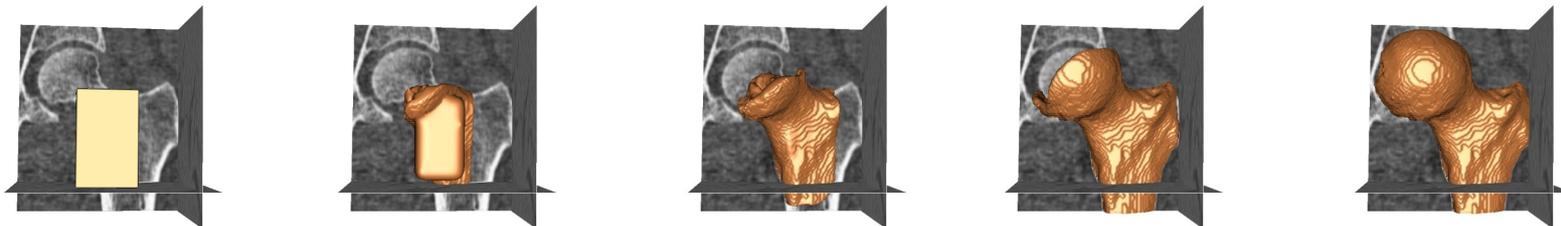


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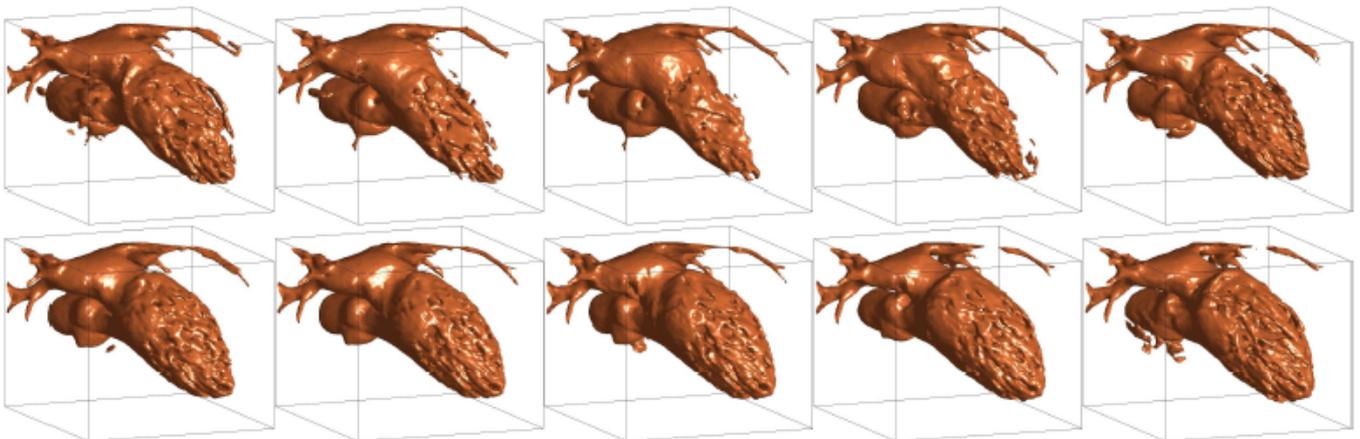
What can we do?

Segmentation

Static image



Moving image



Sazonov, Xie and Nithiarasu, *CMBBME*, 2016
Yeo, Xie, Sazonov, Nithiarasu, *IEEE, TIP*, 2011



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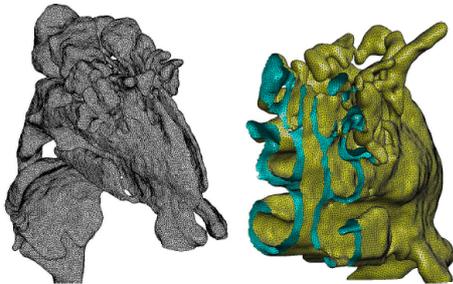
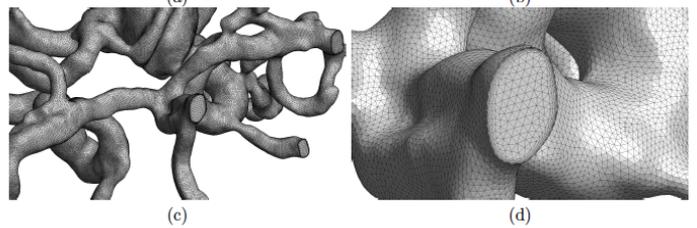
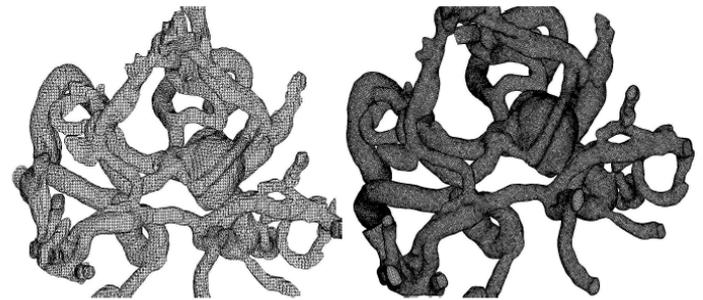
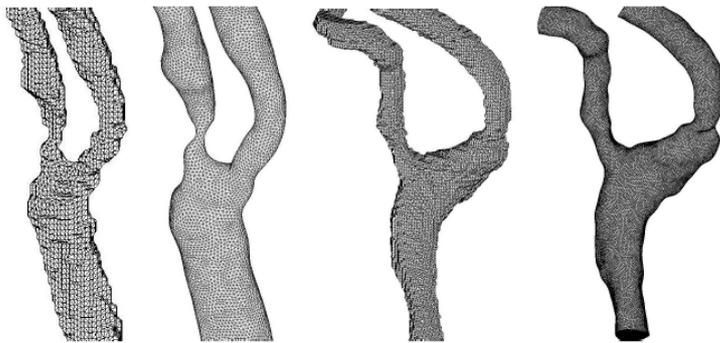
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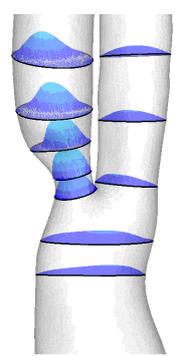
What can we do?

Meshing



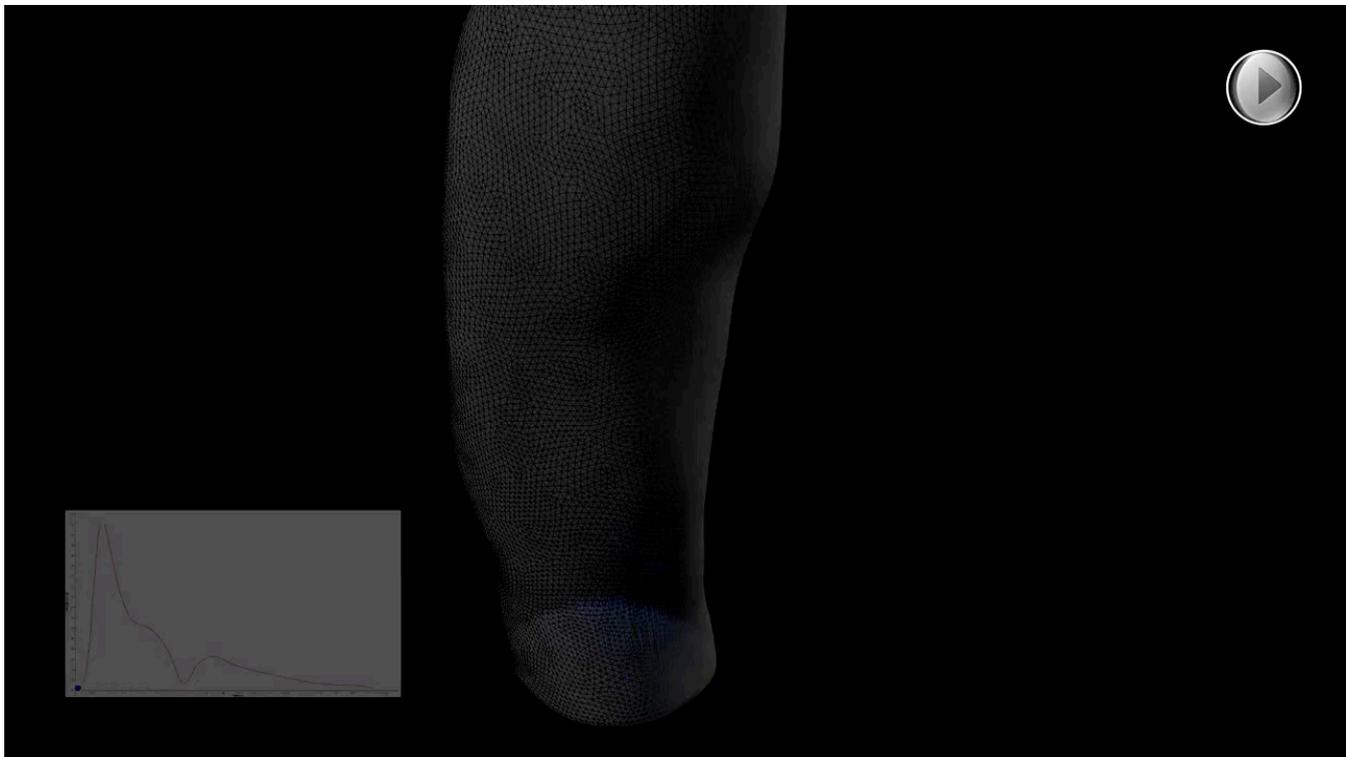
Sazonov and Nithiarasu, IJNMBE, 2012

What can we do?



Carotid artery

Flow



Sazonov, Bevan, Nithiarasu et al., *IJNMBE*, 2011.

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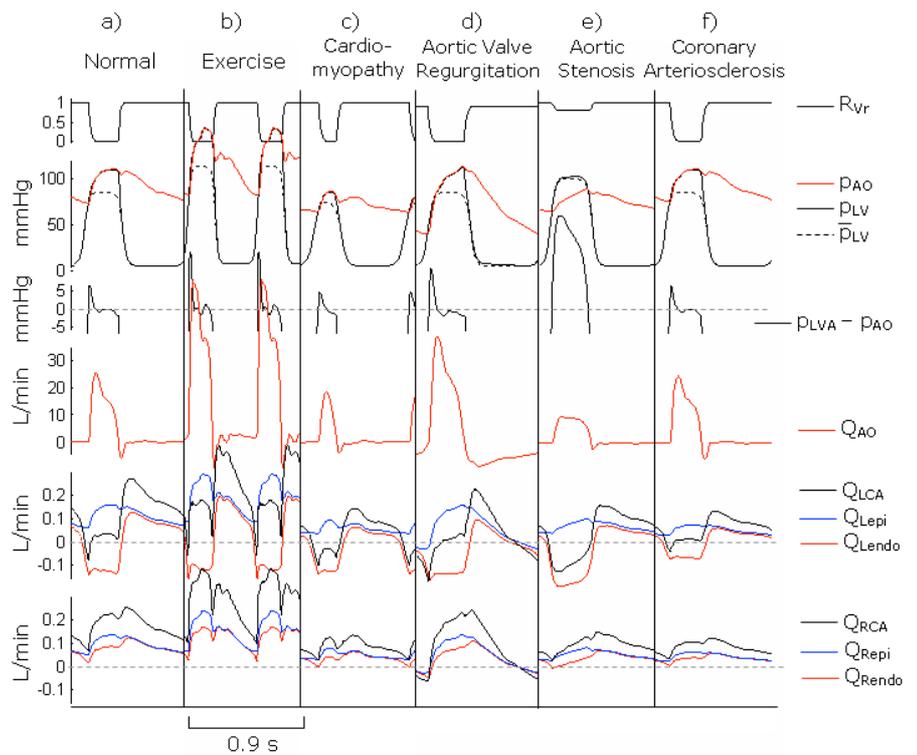
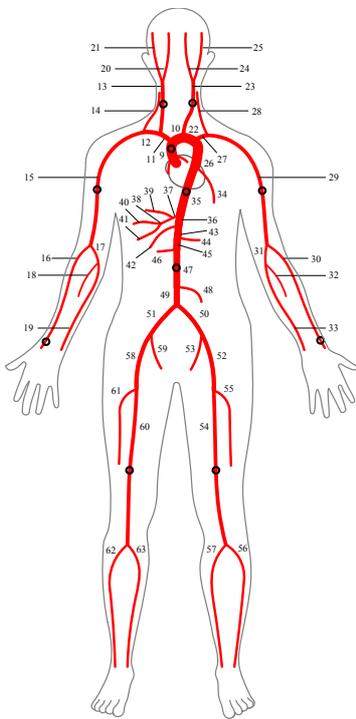
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What about systemic circulation model?

Systemic Circulation - 1D Model



Mynard and Nithiarasu, CNME, 2008.

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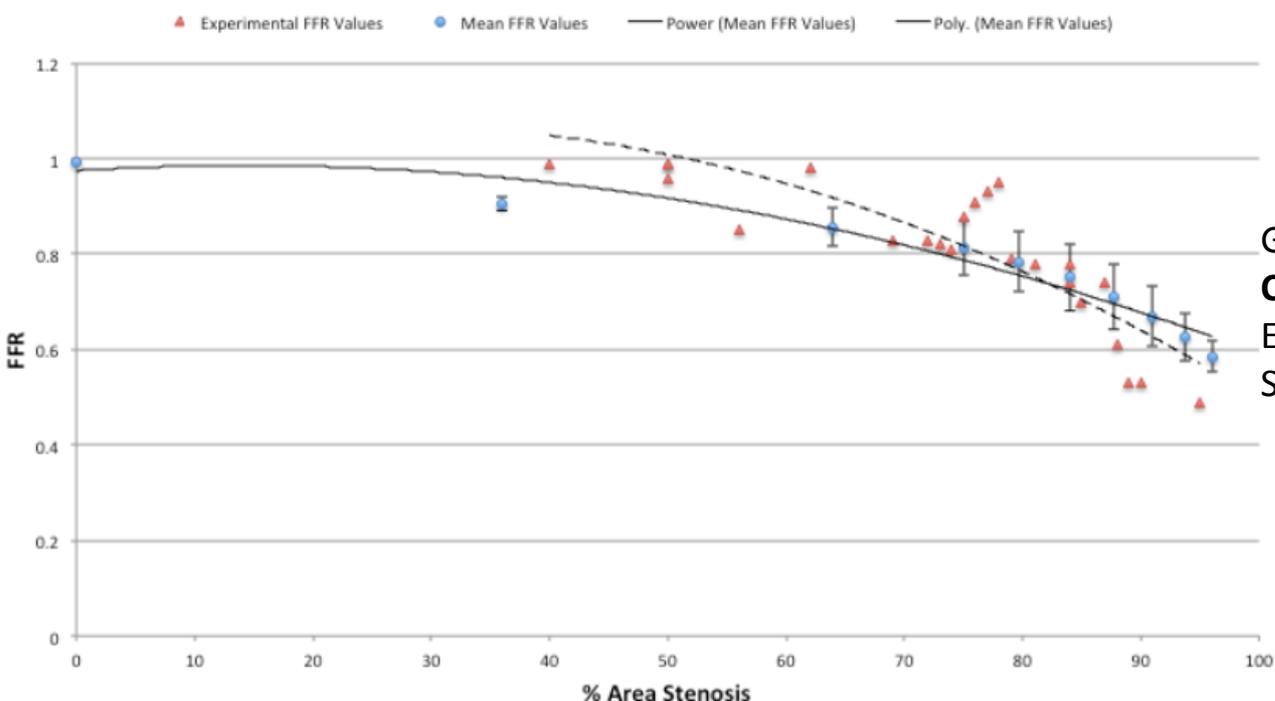
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Systemic Circulation Model - 1DFFR

Chart to show FFR against % Area of stenosis (Model & Experimental values)



Graph:
C.M. Cregg, UG Med
Engg. project, 2014
SU



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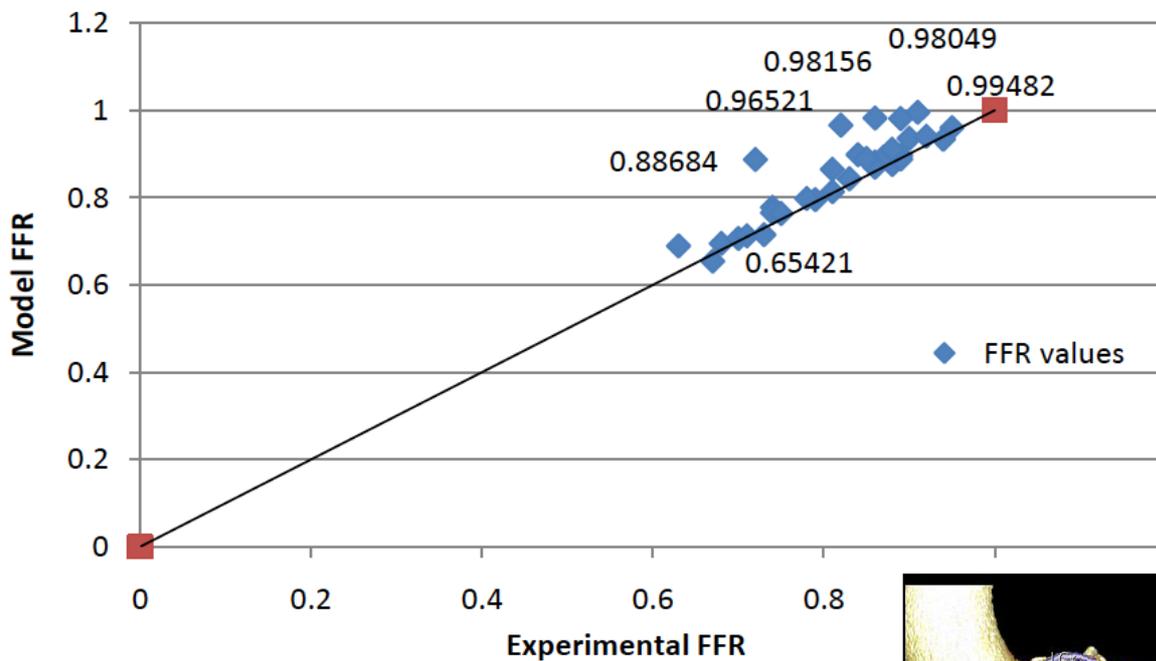
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Systemic Circulation Model - 1DFFR

Lesion	Diam. Stenosis (%)	MAP (mmHg)	MPSP (mmHg)	Measured	MAP* (mmHg)	MPSP* (mmHg)	Numerical
				FFR			FFR*
1	77.6	98	48	0.49	97.8	48.2	0.49
2	68.4	99	52	0.53	100.0	52.3	0.53
5	61.3	90	63	0.70	90.5	63.6	0.70
8	60.0	85	66	0.78	84.8	65.7	0.78
13	47.1	70	58	0.83	70.7	59.3	0.84
19	53.1	95	90	0.95	94.9	88.8	0.94

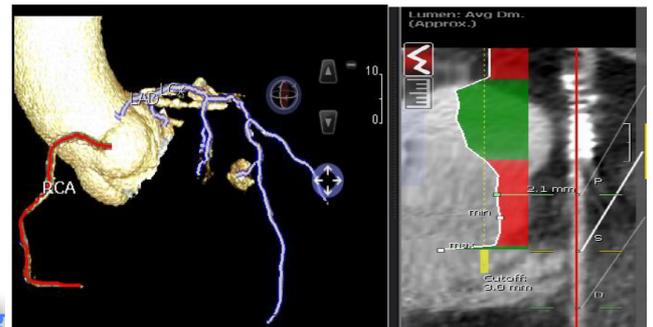
Boileau and Nithiarasu, Springer Book Chapter, 2014

Systemic Circulation Model - 1DFFR with patient-specific information



Patient data:
Plymouth Hospital

Graph:
K.M. El Ghamrawy,
MSc Thesis, SU



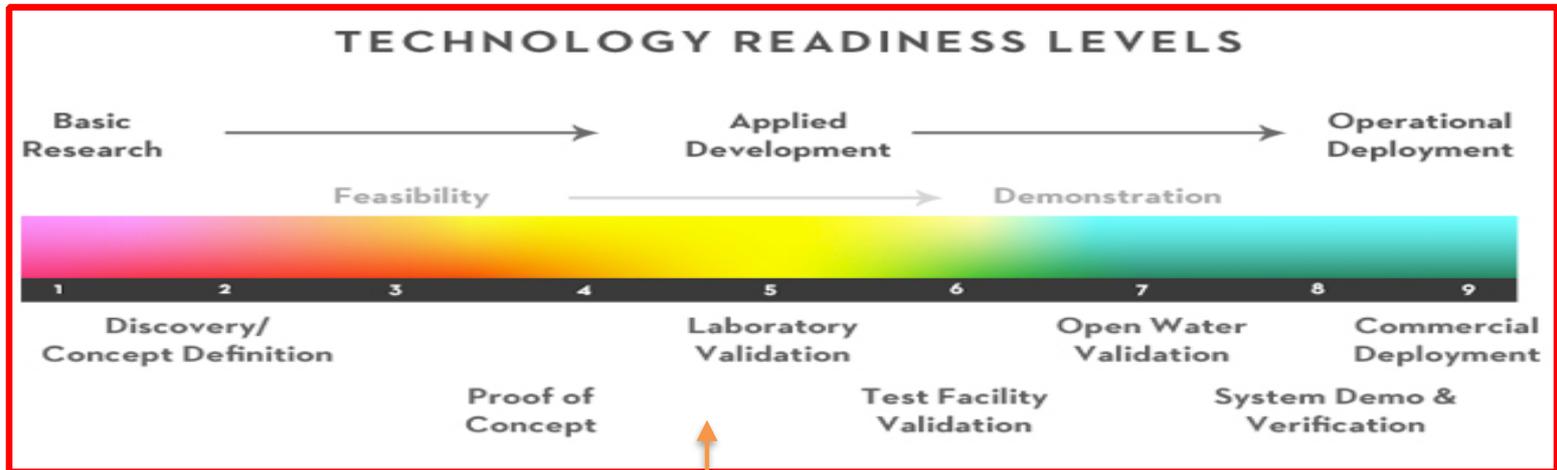
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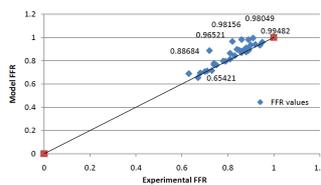


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Systemic Circulation Model - 1DFFR where are we?



FFR Research

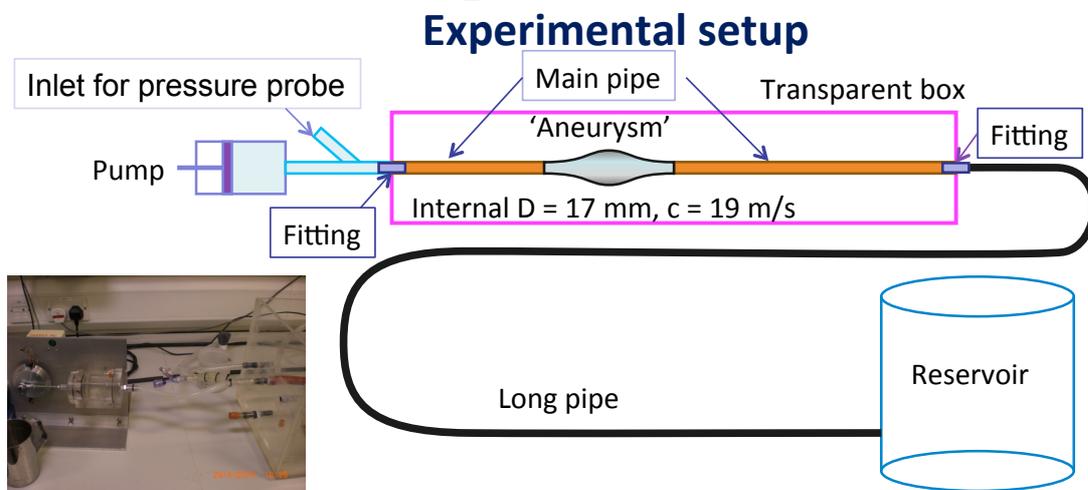


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More targeted research examples: Aneurysm detection



Pump



Main pipe inlet



Long pipe inlet



Reservoir

20/03/16

Sazonov: Pulse reflection from model aneurysm

7

Ashraf Khir's work



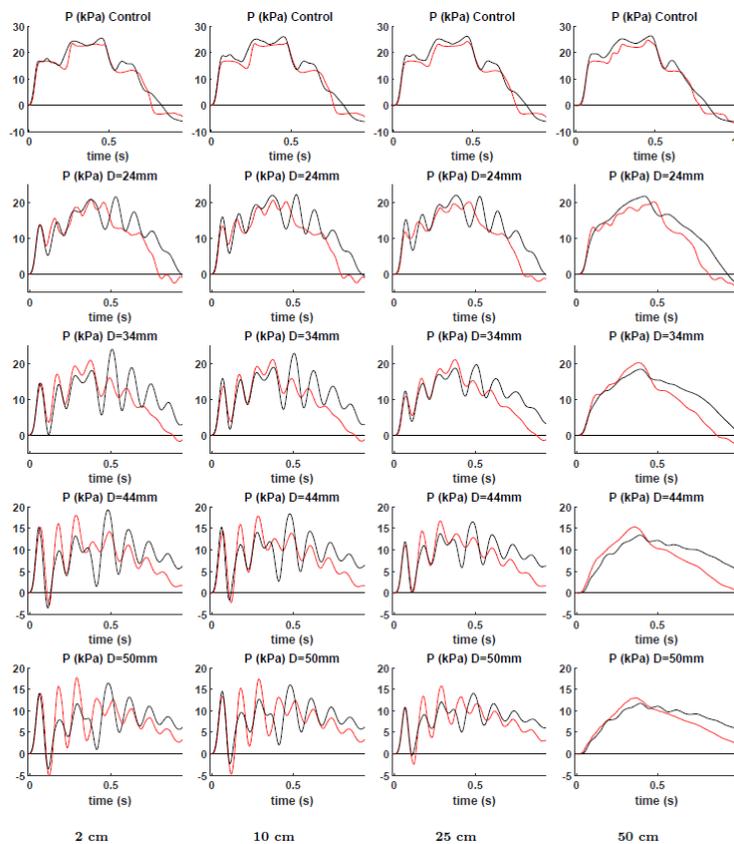
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More targeted research examples: Aneurysm detection



**Black -
Experimental**

Red - Numerical



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Igor Sazonov's work

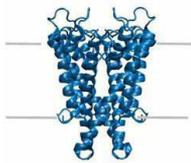
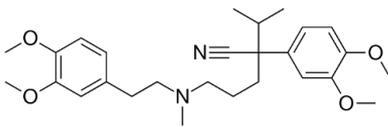
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More targeted research examples: Towards non-invasive drug testing

Molecular level
Experiments



Modelling

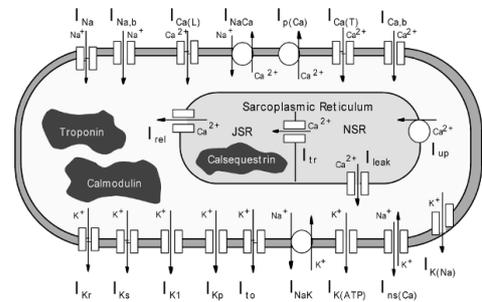
Prediction of
parameters



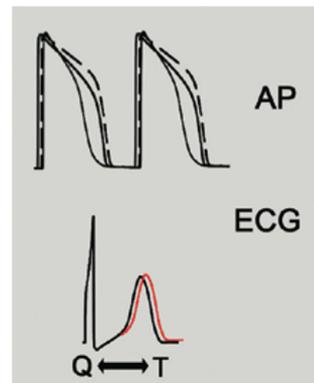
Safety pharmacology

Etienne Boileau's work

Electrophysiology



Modelling



What can we do to increase pathways to impact?

Academics and researchers

- What is on offer should be very clear
- Pathways to impact should be straightforward
- Avoid extraordinary claims
- Establishing contact with regulatory authorities
- Reliability and reproducibility tests

Industries/Clinics

- What triggers industries' interest?
- When to handover to industries/clinics?

Why is it so difficult to make an impact? Biofluid dynamics.

Support from Large Research Centres

Aero/Hydro: Considerable (DLR, Onera, NASA, JAXA, ...)

Established Codes with Hundreds of Developers (TAU, ELSA, ...)

Haemo: No Concerted Effort

Support from Industry

Aero/Hydro: Large, Centralized Enterprise

Considerable Influence on Support/Programs/Lobbying

Haemo: Often commercial codes preferred

Approval Process for Innovations

Aero: Few Norms → Very Fast Pace of Innovations

Hydro: Precedent Cases / Classification Societies → Much Slower

Haemo: Government approval → Very Very Slow

Immediate Benefits

Aero/Hydro: Obvious, Simple Drag/Cost Figures

Haemo: Not Always Clear

Clinical Relevance? Added value?



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UK-Russia Funding Opportunities

UK Side

- **Royal Society - RFBR International Exchange Scheme**
New collaborations between UK and Russian Scientists
Max award: £12,000
- **EPSRC - Networks.** UK-based activities link research groups and industrial organisations
- **H2020** - http://ec.europa.eu/research/participants/data/ref/h2020/wp/2016_2017/main/h2020-wp1617-health_en.pdf
- **British council** - Followup funding for fellowships and workshops.

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USA

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