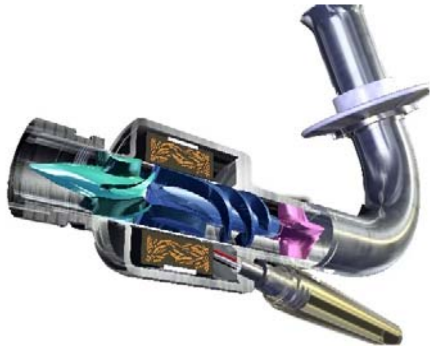
Pro-01: Development and *In Vitro* Evaluation of a Hydraulic System for a Mini-axial Flow Blood Pump

Background: Fully implantable rotary blood pumps are used for mechanical circulatory support of heart failure patients as a bridge to transplant, bridge to recovery or destination therapy. However, device implantation is still a highly invasive procedure and complications include bleeding and infection. Development of a miniaturized axial flow blood pump has the potential to mitigate complications associated with current devices through less invasive implantation techniques.

Aim: The aim of the present project is to design and evaluate the hydraulic system (i.e. housing / impeller) of a new mini-axial flow blood pump.



Tasks: Specific tasks include:

- Update of an existing axial flow blood pump test rig
- 3D design (SolidWorks) of impeller and pump housing prototypes
- 3D printing, manufacturing and *in vitro* bench testing of prototypes including pump characterization (e.g. H-Q curves and pump efficiency)
- Iterative improvement of pump design

Significance: The present project will result in a prototype system for a new mini-axial flow blood pump which will be essential to evaluate the efficacy of the overall project.

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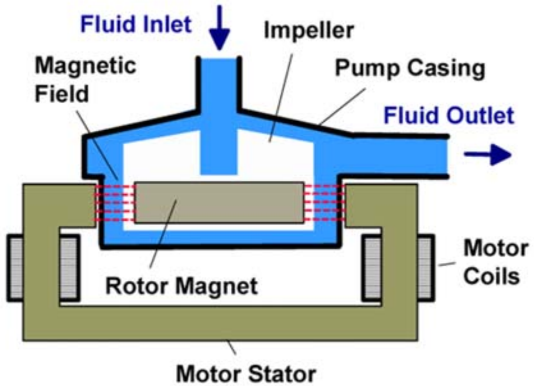
Pro-02: Design and Implementation of a Magnetically Levitated Motor for a Blood Pump

Background: Rotary blood pumps are commonly used as left ventricular assist devices (LVADs) in the treatment of heart failure patients. An essential component of these LVADs is the motor which can be magnetically levitated to minimize mechanical weary. It is expected that the next generation of LVADs will be smaller but powerful enough for full support of heart failure patients. Thus, this project will contribute towards the miniaturization of LVADs.

Aim: The aim of the present project is to design, implement and test magnetically levitated motors for blood pumps.

Tasks: Specific tasks include:

- Design AC synchronous motors: electrical systems (analog and digital systems)
- Develop active control systems for magnetic levitation using Matlab/Simulink, Arduino.
- Fabricate platforms and build experimental setup
- Assemble and test the fabricated prototypes



Significance: This project will result in a prototype of a magnetically levitated motor which will be used for research purposes. This project represents a step forward in the development of miniaturized LVADs and is suitable for students in the following programs: Electronics/Mechatronics/Mechanical Engineering.

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Pro-03: Development of an automated IV Drip Pump

Background: IV drips are the most commonly used medical devices, yet failure rates of these devices are high, with an average of 40% of devices blocking off, leaking into the surrounding tissue, falling out or become painful and infected. Many of these problems stem from the manual and uncontrolled flushing of the IV lines.

Aim: The present project aims to address these problems by designing and evaluating an automated programmable feedback pump capable of delivering a saline solution to a vein at a constant flow with periodic high flow infusions aimed at flushing the catheter. Feedback will be based on blood flow to ensure an optimal flow rate is achieved to avoid damage to the vein.

Tasks: Specific tasks include:

- Design and manufacturing of pump prototype
- Design and implementation of control algorithm
- *In vitro* evaluation of device prototype in a purpose build model vein test rig

Significance: The present project will result in a prototype system for a novel IV drip pump to mitigate adverse events associated with current devices and ultimately improve patient care. The project is a collaboration between the ICETLAB, QUT School of Nursing and QUT Science and Engineering Faculty.

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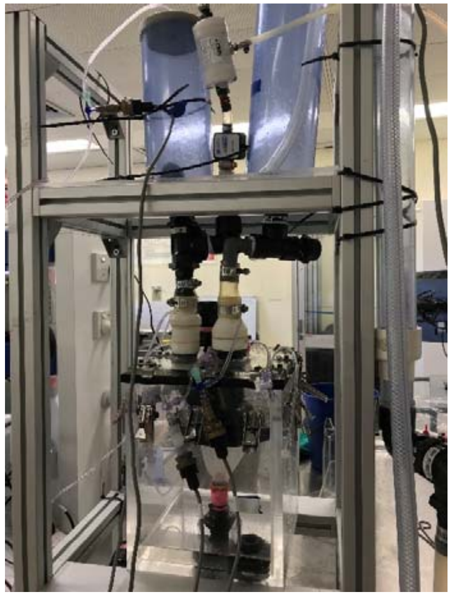
Pro-04: Design and Development of a Right Sided Mock Circulation Loop

Background: Mock circulation loops (MCL) are a mechanical representation of the human cardiovascular system. MCLs are used during *in vitro* evaluation of cardiovascular assist devices such as right ventricular assist devices (RVADs). The use of a patient-specific moulded ventricle within the MCL provides enhanced evaluation of these devices, permitting the implantation of RVAD inflow cannula directly into the ventricle.

Aim: The aim of the present project is to design, construct, and test a right sided MCL, connected to a moulded patient-specific ventricle.



Tasks: Specific tasks include:

- Use CT data to create anatomically correct MCL components, such as a right ventricle
- Develop a fully functional, right sided MCL
- Validate the MCL against patient data and literature.

Significance: This project will result in a purpose build beneficial evaluation tool for the assessment of the right heart in failure and RVADs.

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Pro-05: Improved in-vitro testing of a suture-less inflow cannula using a bioreactor

Background: Current scaffold evaluation techniques are predominantly conducted on tissue culture plates under static conditions. However this is not representative of the physiological environment that the scaffold would experience *in vivo*. There is a need to create a better model to assess the efficacy of scaffolds in the left ventricle.

Aim: Design a bioreactor to mimic different physiological flows, in particular, flows on a cannula at the left ventricular apex.

Tasks: Specific tasks include:

- Determine the flow characteristics required
- Design and manufacture a bioreactor
- Verify flows in the bioreactor
- Analyse the data to determine design improvements

Significance: This project will result in a highly beneficial tool in the assessment of scaffolds in the left ventricle and for other tissue engineering applications.

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Example of a cell culture bioreactor

Pro-06: Comparison of Blood Damage with Different Pulsing Rotary Blood Pumps

Background: Continuous-flow rotary ventricular assist devices (VADs) may benefit from simulating the pulsing flow created by the native heart. However, this may create higher shear forces and subsequent blood damage.

Aim: The aim of this project is to compare the blood damage in pulsatile flow modes with different rotary VADs.

Tasks: Specific tasks include:

- Investigate VAD parameters to produce the required haemodynamics in pulsatile flow modes in different rotary blood pumps
- Compare the blood damage between different rotary blood pumps in pulsatile flow modes.

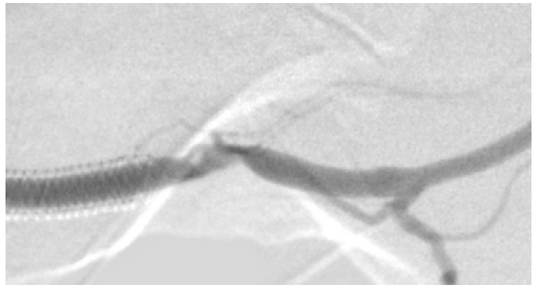
Significance: This project will allow researchers to compare pulsatile performance of different rotary blood pumps.

Red blood cell damage during pulsatile operation of VADs will be investigated in this study.

Contact: Dr Chris Chan: hoihoung.chan@griffith.edu.au

Pro-07: Flow loop for isolated veins

Background: The dilation of veins under the influence of wall shear stress is well documented, but the mechanisms of this are as yet unknown. This project will bring physiologists and engineers together to research the mechanisms of vein dilation.



Pig vein dilated with dosed wall shear stress

Aim: projects will develop a flow loop which can pass blood through isolated veins allowing us to see the dilation of the vein and to measure the biochemistry in the vein sections.

Tasks: Specific tasks include:

- Designing a flow loop with specific connectors which allow attachment to vein sections without blood loss and sampling of blood.
- Setting up a NI Virtual instrument to control the loop + make measurements of flow rate and other electrical signals derived from biochemical processes
- Verify that the loop can accurately duplicate the pulsatile flow of the human circulatory system.
- Help to write a journal paper on the flow loop and measurements

Significance: This project will inform a research project on wall shear stress-mediated vein dilation as part of a research project aimed at increasing access to haemodialysis for patients with kidney failure.

Contact: Prof Geoff Tansley: g.tansley@griffith.edu.au

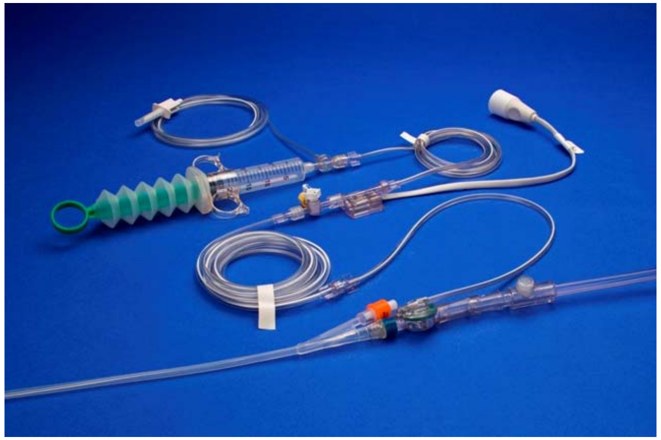
Pro-08: Intra-abdominal Pressure Measurement System

Background: Following surgery it is commonplace to measure the intra-abdominal pressure of the patient. Typically this is carried out using a catheter which is passed in to the bladder and which is uncomfortable for the patient and unpleasant for the nursing staff.

Aim: The aim of this project is to design and test a device which can measure the intra-abdominal pressure and remove the need for bladder catheterization.

Tasks: Specific tasks include:

- Review current catheterization techniques.
- Design and construct a pressure measuring system.
- Test the pressure measuring system in-vitro (and maybe in-vivo) and compare its performance with current methods.



Bladder Catheter for IAP measurement
(AbViser™)

Significance: Such an intra-abdominal pressure measurement system would reduce the need for invasive interventions and could lead to much more frequent and accurate measurements.

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Pro-09: In-silico (and In-vitro) fluid mechanics of Coronary Arteries

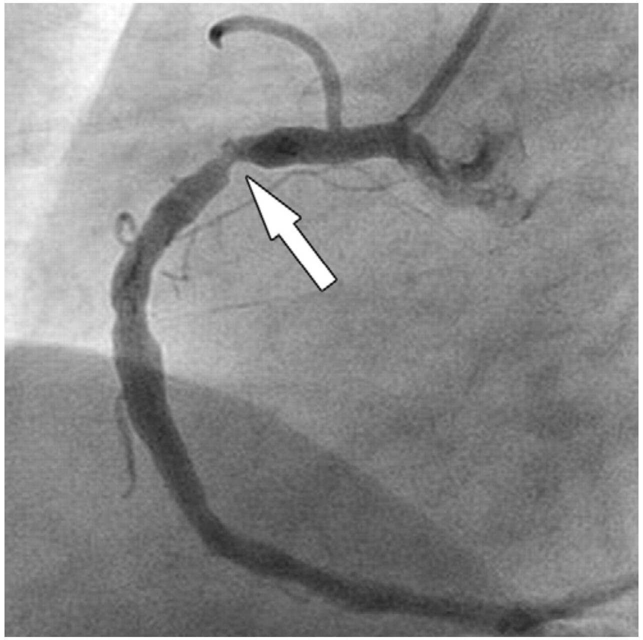
Background: Blockages and narrowing in coronary arteries can lead to angina and heart attacks. We have a database of models of human arteries with clinical flow data.

Aim: The aim of this project is to 3D model these arteries and predict flow and shear stress through them and compare this to the clinical situation.

Tasks: Specific tasks include:

- Develop 3D models from Dicom images
- Apply CFD modelling to extract fluid dynamical data
- Compare CFD models with clinical data
- (maybe also make physical models of the arteries and use PIV to validate the CFD data).

Significance: Such models will assist surgeons in deciding whether a stenosis is critical and whether to operate on an individual or not.



Coronary stenosis

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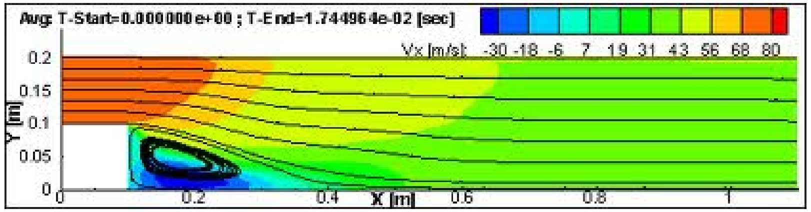
Pro-10: Haemolysis modelling in a backward-facing step

Background: Shear stresses are known to destroy red blood cells (a process known as haemolysis). As yet there is no good CFD model for haemolysis but the FDA has proposed generation of such a model which can be benchmarked for accuracy across many labs. This model comprises a backward-facing step which was a benchmark many years ago for turbulence modelling.



CFD over a backward-facing step (from http://ivancic.de/cfd2k/Gallery.html)

Aim: Create a computational (CFD) model of a backward facing step informed by open literature. In parallel, create a physical blood flow loop of the same configuration and predict haemolysis from shear stress fields compared with physical measurements of haemolysis.

Tasks: Specific tasks include:

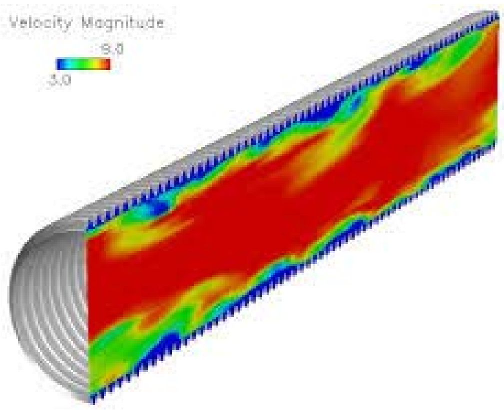
- Review current models of backward-facing steps in literature
- Develop a CFD model of the backward-facing step
- Develop a physical model of the backward facing step and measure haemolysis in it.

Significance: This project will feed in to an international effort to develop a reliable CDF predictor of haemolysis

Contact: Prof Geoff Tansley: g.tansley@griffith.edu.au

<u>Pro-11: Haemolysis modelling in pipes of varying roughness</u>

Background: Shear stresses are known to destroy red blood cells (a process known as haemolysis). As yet there is no good CFD model for haemolysis – a process which is known to be very strongly influenced by shear stresses at the pipe walls (rather than bulk flow). This project will model flow in pipes of varying roughness to examine the significance of roughness on shear stress and haemolysis and CFD wall modelling on its prediction.



CFD in Pipe Flow (from http://www.acusim.com/ html/applications.html)

Aim: Create a computational (CFD) model of pipes of varying diameters and wall roughness, and in parallel, create a physical blood flow loop of the same configuration and predict haemolysis from shear stress fields compared with physical measurements of haemolysis.

Tasks: Specific tasks include:

- Review current models of CFD haemolysis predictions in literature
- Develop a CFD model of pipes of varying diameter and wall roughness
- Develop a physical model of pipes of varying diameter and wall roughness and measure haemolysis.

Significance: This project will feed in to an international effort to develop a reliable CDF predictor of haemolysis.

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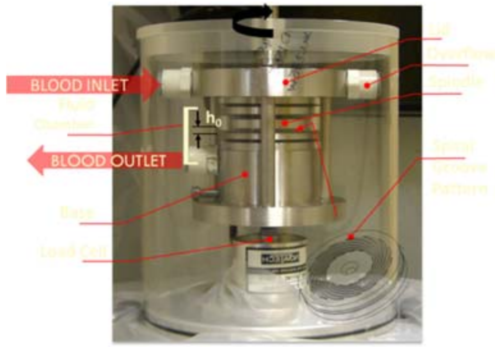
<u>**Pro-12: Cell exclusion and Haemolysis in a Spiral Groove Bearing**</u>

Background: Anecdotal evidence shows that red blood cells avoid flowing through very tight gaps (e.g. in spiral groove bearings) in rotary blood pumps and that this behaviour saves the red blood cells from damage. We have been able to show photographically this behaviour but not to confirm protection of the red cells.



Spiral Groove Bearing apparatus from Leslie et al 2012.

Aim: To replicate a spiral groove bearing in the lab and to gather photographic evidence of cell exclusion and protection against cell damage (haemolysis).

Tasks: Specific tasks include:

- Set up a bench-top milling machine + add new control software
- Design and make equipment for spiral groove experiments
- Set up a laser-based system to gain photographic evidence of cell exclusion
- Carry out blood flow experiments to show a reduction in haemolysis where cell exclusion processes are at work.

Significance: Bearing design in blood pumps is a significant problem and we hope through this project to draw up design code for commercial blood pump designers.

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