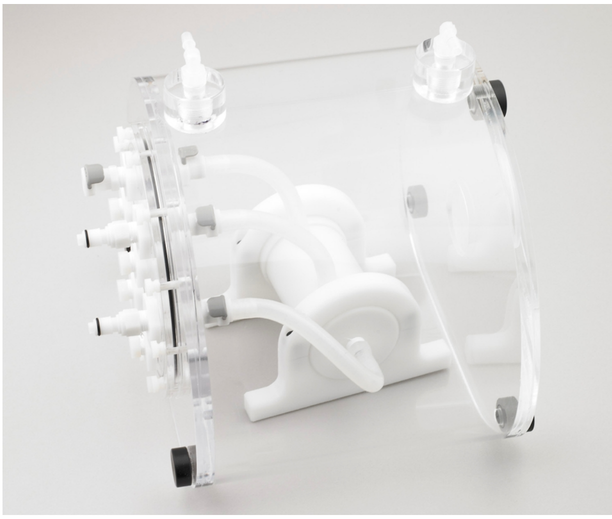
MULTI-MODALITY DCE PERFUSION FLOW PHANTOM



Shelley Medical's programmable Multimodality Dynamic Contrast Enhanced (DCE) Perfusion Flow Phantom simulates in vitro blood flow and two-compartment contrast flow pharmacokinetics using pressure-controlled fluid exchange with either step function-based or typical clinical arterial input function (AIF) inputs.

This novel phantom produces a wide range of predictable, reproducible and quantifiable time concentration curves (TCCs), which generate a wide range of realistic input and output functions simulating clinically relevant perfusion TCCs. The ability of this phantom to generate DCE quality assurance protocols with realistic flow provides an excellent framework for the validation of perfusion and kinetic modeling, and enables DCE imaging to be utilized as a quantitative imaging tool to compare scanners within an imaging modality, or across CT, MRI & PET modalities, and to compare imaging protocols.

The accompanying DCE Phantom Prediction Software accurately and reproducibly predicts the TCCs that will be rendered when the phantom is scanned for a given selection of input parameters. At the same time, a wide range of physiologically relevant enhancement profiles can be modeled, users can define a desired TCC and the required input parameters to the phantom will be calculated. Simple to use DCE Phantom Prediction Software allows the user to select the following; CT, MR or PET imaging modality, the maximum time, injection parameters, output flow rate and perfusion pump flow rate.

Product Applications

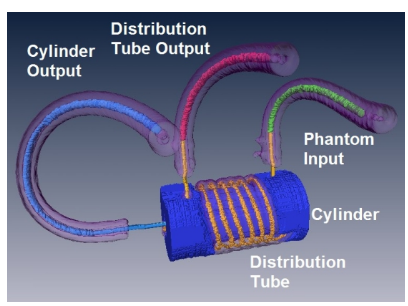
- CT
  - Perfusion/DCE CT
  - Image noise & Partial volume effect quantification
  - CT number linearity and sensitivity
- MR
  - Magnitude and Phase based DCE-MR
  - Arterial Spin Labeling (ASL)
- Dynamic PET
- Comparison of scanners within individual modalities
- Multi-modality comparison of scanners
- Kinetic Model Validation
- Evaluate the interplay between dynamic contrast flow and dynamic image acquisition.

Product Features

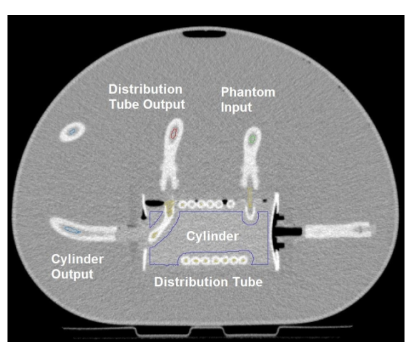
- Multimodality DCE Flow Phantom
- Compatible with; X-ray computed tomography (CT), magnetic resonance (MR) and positron emission tomography (PET) imaging modalities.
- Create a wide range of physiologically relevant time concentration curves under physiological and steady-state flow rates (TCCs) comparable to those observed clinically in Perfusion CT/MR.
- Accurate and highly reproducible contrast measurement in a dynamic setting.
- Predictable and reproducible time enhanced curves.
- Perform CT number linearity and sensitivity testing to convert CT number enhancement to concentration
- DCE Prediction Software
- Easy to use automated DCE Phantom Prediction software for CT, MRI & PET imaging generates a wide range of clinically relevant and reproducible contrast enhanced curves.
- Model data is easily exported to a MATLAB data file or an Excel spreadsheet.
- Provides a baseline contrast calibration curve.

Product Benefits

- Provides a ground truth imaging modality comparison of scanners within the CT, MRI & PET modalities, providing a gold standard across multiple imaging platforms.
- Dynamic acquisition protocol development to improve dose efficiency.
- Improve quantitative contrast-enhanced imaging and quantify scanner variability
- Assess individual scanner sensitivity using time attenuation curves generated by the phantom.
- Perform a basic ROI sensitivity analysis test on different CT scanners and acquisition protocols.
- Further validation of kinetic model parameters.



The regions of interest of the phantom displayed as 3D surfaces.



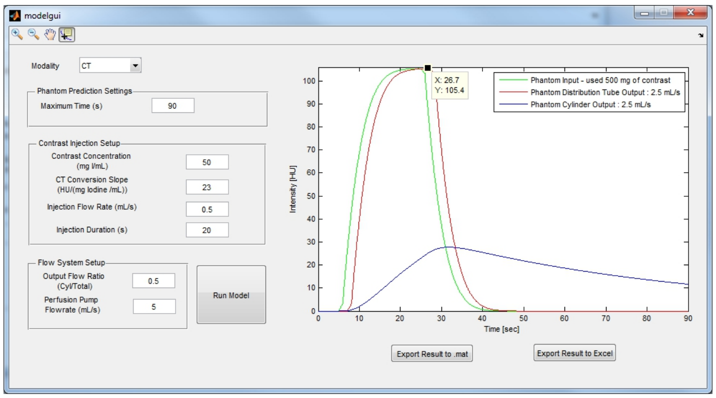
A single axial slice of the dynamic flow phantom submerged in the acrylic shell phantom depicting the manually contoured regions of interest.

Prediction Application Operation

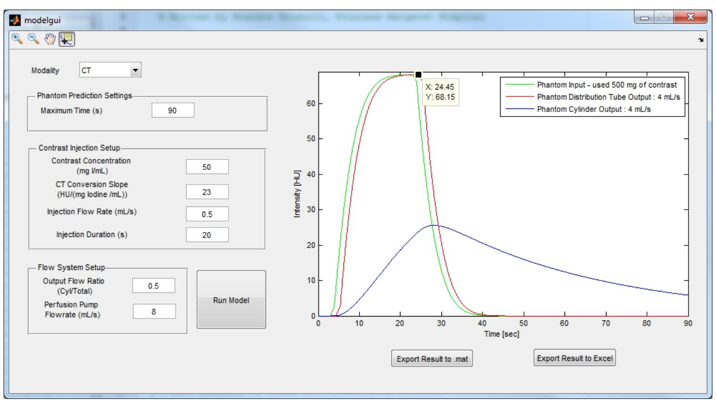
The Dynamic Perfusion Flow Phantom prediction software predicts the enhancement profile to be rendered when the user scans the Phantom using matching input parameters. The prediction software models time enhancement curves with those displayed by the Dynamic Perfusion Flow Phantom for CT, MRI & PET.

The following Default Input Model cases outlines the regular operation of the Dynamic Perfusion Flow Phantom prediction application. *These examples use computed tomography (CT), but the demonstrated effects are also true for MRI and PET Imaging modalities.*

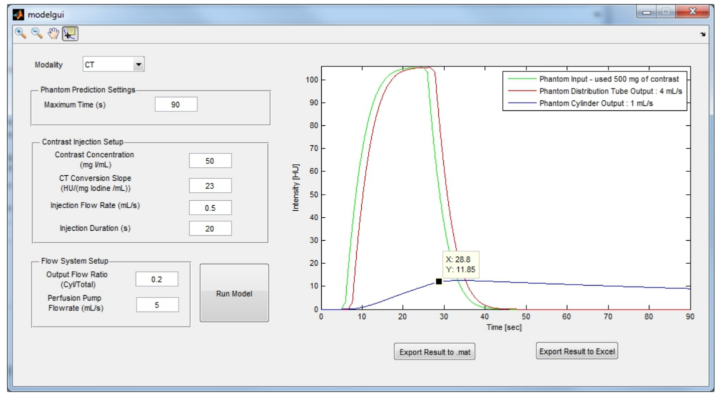
CASE #1 Default Input Model
The *Output Flow Ratio* is set to 0.5, which implies that the flow rate from each output tube is equal.



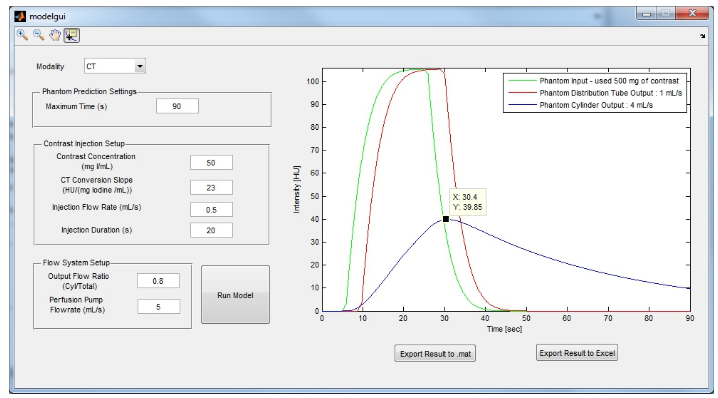
CASE #2 Default Input Model
The *Perfusion Pump Flow Rate* is increased from the default 5.0 mL/s to 8.0 mL/s.



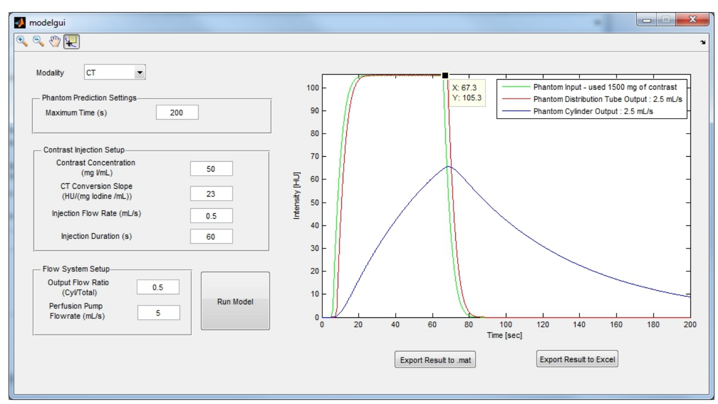
CASE #3a Default Input Model (see top right graph)
Output Flow Ratio is decreased from 0.5 to 0.2. By modifying the flow distribution such that 20% of the total flow is directed through the cylinder and 80% is directed through the distribution tube, a very low *Phantom Cylinder Output* intensity peak is produced.



CASE #3b Default Input Model
Output Flow Ratio is decreased from 0.5 to 0.8. By modifying the flow distribution such that 80% of the total flow is directed through the cylinder and 20% is directed through the distribution tube, a sharper and higher *Phantom Cylinder Output* intensity peak is produced.

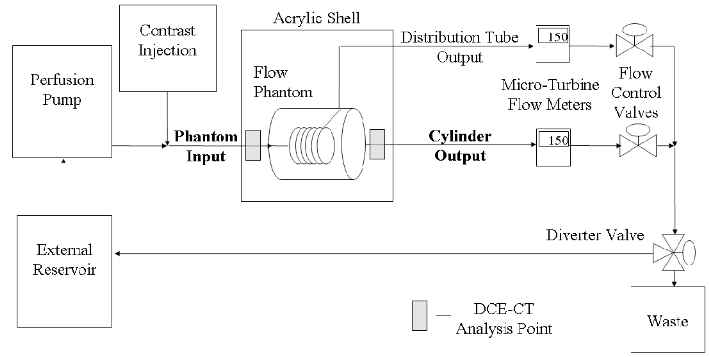


CASE #4 Default Input Model
This model modifies the Injection Duration from 20 s to 60 s; the Maximum Time parameter is increased to 200 s to obtain a complete view of the enhancement profile. Since the *Injection Flow Rate* and *Contrast Concentration* are conserved at default CT values, the *Contrast Used* value increases with increasing *Injection Duration*, resulting in 1500 mg of contrast being used in this case as compared to the default value of 500 mg.



The phantom input and distribution output tube peaks are nearly equal in magnitude to those produced in Case 1; although the amount of contrast agent entering the system is greater in this case, the concentration and flow properties of these flow streams are consistent with those of the default model and result in the same incoming contrast concentration. An equilibrium (peak) intensity value is reached after approximately 25 s and then drops sharply to 0 HU approximately 7 s after the injection stops, representing the passing of the contrast bolus.

The increased amount of contrast results in a higher cylinder output tube intensity peak and the longer injection duration results in the peak occurring later in the simulation, approximately 65.0 HU and 67.3 s, respectively. The increased magnitude of this peak is attributed to the contrast accumulating in the cylinder as a result of its large volume, poor mixing, and thus, long residence time.



Hardware Specifications

Torso Shell, made of acrylic and sealed

Fluid Mass Exchange Cylinder which embodies a spiraling interior perforated distribution tube with input and output tubes.

Injection Port complete with backflow prevention, syringe port and required fittings for typical clinical IV administration.

Needle Valves Control (2)
- ¼” (6.35 mm) ID carbon steel for CT/PET
- ¼” (6.35 mm) ID polypropylene for MRI

Turbine Flow Meters (2):
- 50-500 ml/min range (1/8” ID or 3.175 mm)

Turbine Flow Meter Power Supplies (2)

3-Way Ball Diverter Valve: ¼” ID, brass

Tubing
- 14 feet (4.2672 m), ¼” (6.35 mm) ID high pressure clear PVC tubing, food grade
- 3.70 feet (113 cm), 1/8” (3.175 mm) ID clear PVC tubing, chemical resistant
- 5 feet, (152.40 cm), ¼” (6.35 mm) high temperature silicone soft rubber tubing

Software Specifications

Windows only executable files (Linux or Mac operating systems must use a Windows emulating program).

32-bit & 64-bit software versions

MATLAB Compiler Runtime (MCR) version 7.17 (R2012a). The MRC allows the execution of MATLAB applications in the absence of the full MATLAB program.

Optional Pumps

CompuFlow 1000 for non-MRI applications requiring physiological flow and constant flow profiles.

CompuFlow 1000 MR for MRI applications requiring physiological flow and constant flow profiles.

Alternatively a pump with a flow range of 0.5 to 10 mL/s and a pressure shut-off of 50 PSI.

User supplies; contrast injection device, contrast agent, computer for the Predictive Software, external reservoir, and a waste container (20L).

References:

Driscoll B, Keller H, Coolens C. **Development of a dynamic flow imaging phantom for dynamic contrast-enhanced CT.** Med Phys. 2011 Aug;38(8):4866-80.

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Patent Pending

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