PreClinical IceWater DWI Phantom Preparation and Scan Procedure

NCI-CIRP Phantom Round Robin

Version 20211117

I. OBJECTIVE

Quantify repeatability and reproducibility across multiple NIH/NCI Co-Clinical Imaging Research Resources Program (CIRP) preclinical MRI systems in performing diffusion measurement using a standardized diffusion weighted imaging (DWI) protocol applied to a common phantom containing temperature-controlled medium of known diffusivity.

II. OVERVIEW

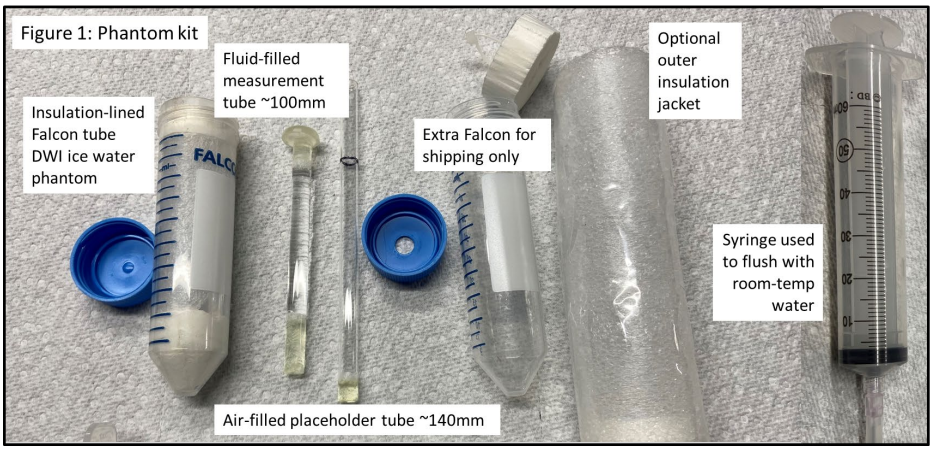
A single DWI phantom kit will be circulated amongst CIRP sites for DWI scanning on their respective preclinical MRI systems. For repeatability, each site is expected to prepare and scan the phantom twice (on different days) on at least one MRI system using the protocol described below, then ship the phantom kit onto the next site in a timely manner (within ~1-2 week). Each site is to generate their own ADC maps and perform ROI measurements using their preferred analysis platform. Sites are to provide scanner-native raw data, reconstructed DWI and ADC maps in an ITK-compatible format (egs. DICOM, NIFTI, MHD etc.) for data sharing and centralized analysis. Data from all sites/systems will be used to assess absolute ADC bias and uniformity along z-axis (over ~30-40mm extent), SNR, repeatability, and reproducibility. The intent is to submit this material for publication. This round-robin phantom experiment may also serve as precedent to guide future CIRP network phantom/protocol/data/analysis tool/SOP collaborations.

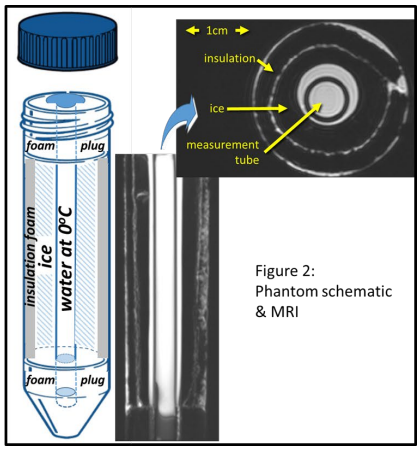
III. PHANTOM DESIGN

The ice water DWI phantom kit is shown in Figure 2. The phantom is designed to surround the fluid-filled central "measurement tube" (8mm OD, ~100mm long) with water maintained at 0°C encased within an ice cylinder (Figure 2). The Falcon tube is lined by foam outside the ice cylinder to provide insulation to extend thermal hold time at ~0°C. The foam lining also allows for volume expansion as the ice freezes otherwise the Falcon tube would burst. A long (~140mm) air-filled glass tube is inserted in the phantom during freezing to serve as a placeholder for the measurement tube. The air-filled tube is replaced by the measurement tube immediately prior to DWI scanning. Note, two copies of fluid-filled and air-filled glass tubes are provided in case a tube breaks.

At a minimum, ***the inner diameter of MRI system's RF coil(s) must be able to accommodate the 30mm diameter 50ml Falcon tube phantom***. If the RF coil(s) can accommodate 40mm diameter, it is recommended to scan the phantom within either of two additional outer foam insulation tubes (provided in kit) to further extend ~0°C hold time, thus extend its usable period.

Check water-filled measurement tube for an air bubble. If present, use provided 3cc syringe with blunt needle inserted alongside of foam plug (as shown at right) and inject distilled water to remove bubble.

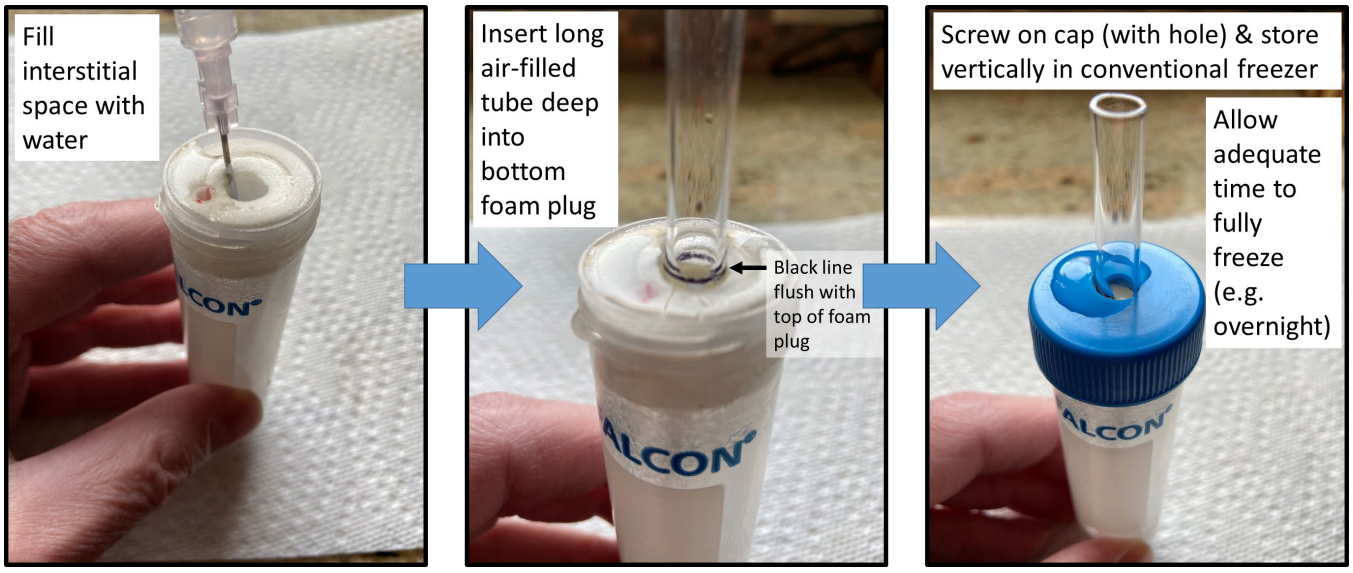




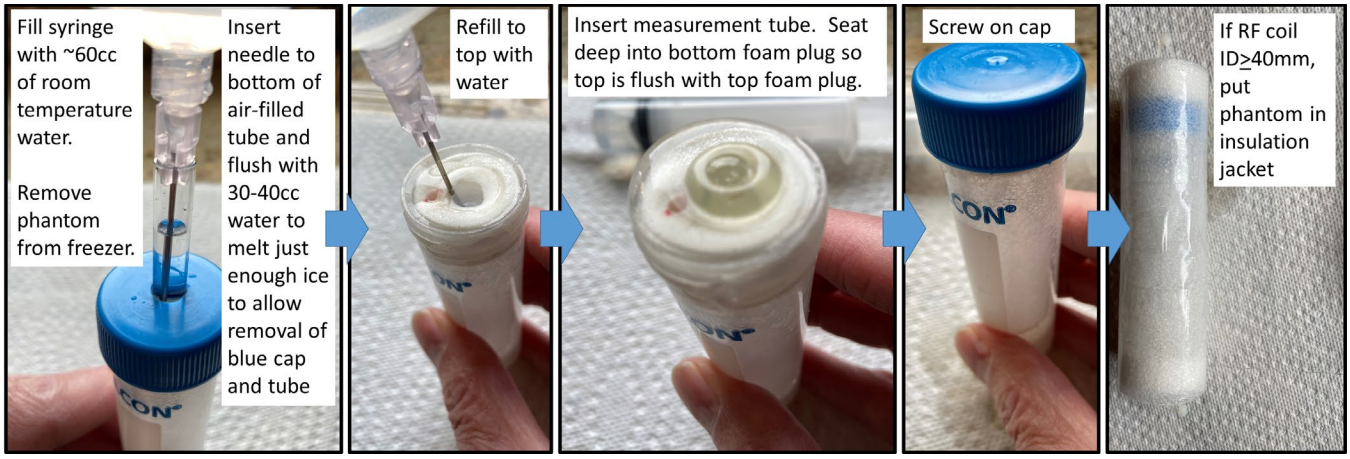
IV. PHANTOM PREPARATION

- ***<u>Plan Ahead:</u>***
  - ✓ *Allow adequate time for interstitial water to fully freeze. Overnight in a conventional freezer is recommended.*
  - ✓ *Build the MRI/DWI acquisition protocol (defined below) well ahead of scanning.*
  - ✓ *Plan to perform MRI scanning immediately after insertion measurement tube such that DWI acquisition happens while the measurement tube is at 0°C (within ~1.5hrs of tube insertion).*

- Phantom freeze:



- *Do following steps **quickly** and just prior to MRI scanning*. Insert measurement tube via steps below:



V. PHANTOM MRI / DWI SCAN PROTOCOL:

Positioning:

Position with long axis of phantom along MRI bore (z-axis) with center measurement tube at magnet & gradient isocenter.

Scanning Day 1:

1. Survey - Acquire large FOV (~80mm) survey series that includes axial, sagittal and coronal sections through the center of the phantom. Other than large FOV, site-preference for survey parameters is acceptable.
2. DWI SCAN1 – Using parameters in Table 1.
3. DWI SCAN2 – Repeat - KEEP ALL TRANSMIT/RECEIVE GAINS CONSTANT. Use identical parameters as DWI SCAN1.
4. (Optional) Site-preferred alternative DWI method.

Scanning Day 2: Repeat steps performed on Day 1. Transmit/receive gains may differ from Day 1, though hold gains constant between Scan 1 and Scan2 of Day2.

Table 1: DWI Acquisition Parameters

Parameter	Target Value	Record Actual Used Value
Scanner Mfg / Model / SWver	Any	
Field Strength	Any	
Receiver Coil	Any	
DWI Encoding Sequence	Mono-Polar Spin-Echo DWI; δ=5ms; Δ=10ms	
Spatial Encoding Sequence	Multi-slice; Single Spin-echo; Cartesian	
Acquisition Plane	Axial (X-Y)	
FOV	32mm x 32mm	
Acq Voxel Size	0.5 x 0.5 x 2mm	
Acq Matrix (freq x phase)	64 x 64	
Recon Voxel Size	(0.5 x 0.5 x 2mm) to (0.25 x 0.25 x 2mm)	
Recon Matrix	(64 x 64) to (128 x 128)	
Parallel Imaging	No acceleration	
Phase Encode Direction	Vertical = Y	
Frequency Encode Direction	Horizontal = X	
Number of Slices	29, HAVE MIDDLE SLICE AT ISOCENTER	
Slice thickness	2mm	
Slice gap	0mm	
B0 Shim	Default volume shim over full phantom	
Fast Imaging Mode	No	
Shot Mode; Number of shots	1 ph-enc per shot; 64 shots	
Partial Echo	No	
TE	30ms	
Flip Angle	90deg	
TR	2000ms	
Water-fat shift	Minimum	
Fat suppression	None or “Default”; do not perform “STIR”	
DWI Encoding Directions	Three orthogonal	
b-values	0[§], 1000, 2000 s/mm^2	
Number of averages	1	
Geometry Correction	Default	
Bandwidth in Freq-dir	Minimum consistent with TE=30ms	
Scan Duration	~15minutes	

[§] If “b=0” cannot be acquired, use minimum low b-value ≤ 50 s/mm^2

VI. IMAGE ANALYSIS – Performed by each site, as well as by central analysis:

1. Generate trace-DWI acquired in DWI SCAN1 and DWI SCAN2 in ITK-compatible format (DICOM, NIFTI, MHD, etc).
2. Generate ADC maps from mono-exponential fit of trace-DWI vs b-value acquired in DWI SCAN1 and DWI SCAN2 and save ADC maps in ITK-compatible format.
3. Define 4mm-diameter circular ROIs on each measurable slice for record of ADC mean and standard deviation in an excel spreadsheet or in table below (in $x10^{-3}mm^2/s$ or $\mu m^2/ms$ units).
4. Fill-in table or provide spreadsheet containing:

	DWI SCAN1:		DWI SCAN2:		(option.) Site-Alt DWI SCAN:	
Slice #	ROI Mean	ROI StDev	ROI Mean	ROI StDev	ROI Mean	ROI StDev
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						

VII. DATA UPLOAD:

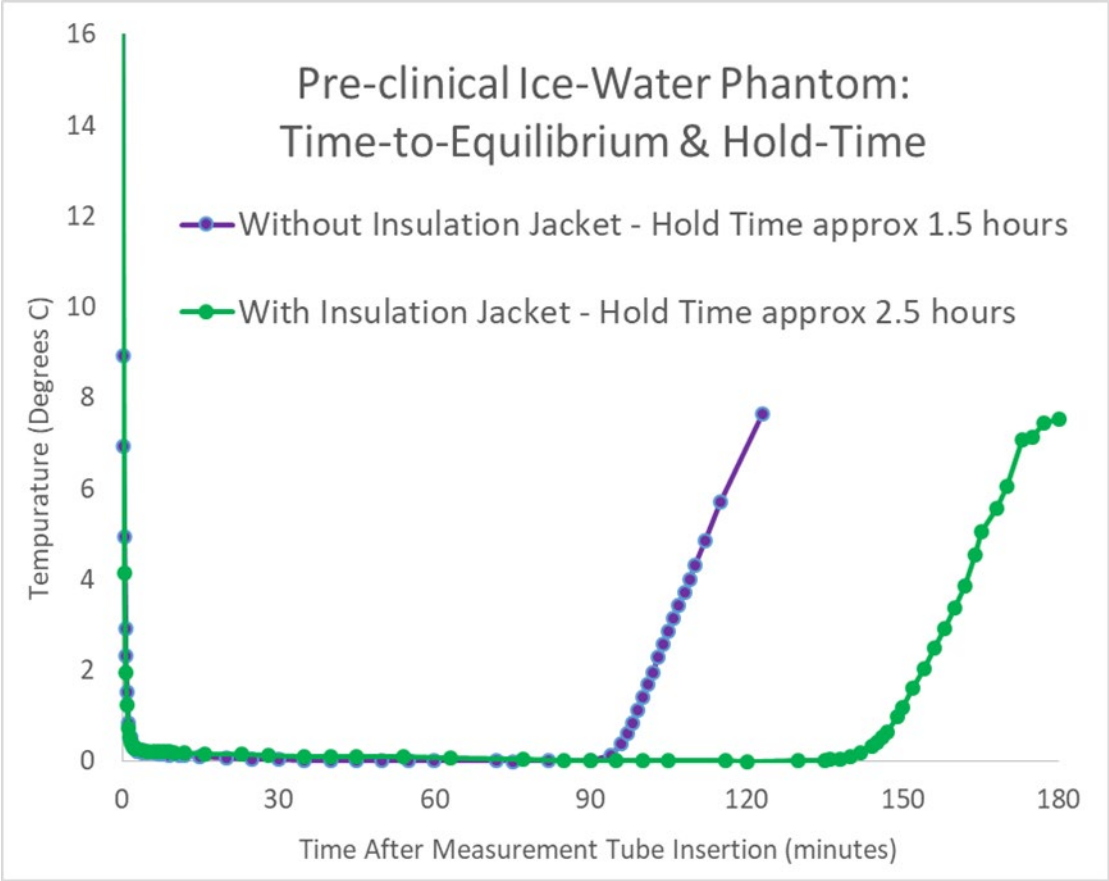
A shared Drop_Box folder will be established for upload of following data:

1. Full exam in the MRI scanner's native/raw data format
2. Trace DWI at b = 0, 1000 and 2000 s/mm^2 in ITK-compatible format
3. ADC maps via mono-exponential fit over all b-values in ITK-compatible format
4. Acquisition parameter datasheet noting deviations from Table 1 (if any)
5. Site's ROI analysis data/spreadsheet

VIII. CIRP ICE-WATER PHANTOM KIT ROUND-ROBIN CIRCULATION RECORD:

****** By email, confirm next contact is able to receive the phantom and provide ship tracking # ******

Site	Contact	Shipping Address	DWI Data Uploaded	Site Analysis Performed
UMich	T Chenevert tlchenev@med.umich.edu Phone: (734) 936-8866	Attn: Tom Chenevert Univ of Mich Hospital Dept of Radiology - MRI 1500 East Med Ctr Drive Rm UH B2 A209 L Ann Arbor, MI 48109-0030	Done	Done
MDACC	S. Gammon STGammon@mdanderson.org Phone: 314 610 0913	Attn: Seth Gammon 3SCR4.3622 1881 East Road Houston, TX 77054	Done	Due
UPenn	R. Zhou rongzhou@pennmedicine.upenn.edu Phone: 215-746-8747	Attn: Rong Zhou Suite 198 John Morgan Building 3620 Hamilton Walk University of Pennsylvania Philadelphia, PA 19104 Phone 215-746-8747	Done	Done
Duke	G Allan Johnson gjohnson@duke.edu Phone: 919 971 3214	Attn: G.A. Johnson Rm 141 D Bryan Neuroscience Bldg Durham, NC 27710		
WUSTL	James Quirk jdquirk@wustl.edu Phone: (314) 362-3875	Attn: James Quirk 4523 Clayton Avenue (Radiology) St. Louis, MO 63110	2 of 3 systems	Due
Baylor	Robia G. Pautler rpautler@bcm.edu Phone: 832-274-2323	Atten: Robia Pautler One Baylor Plaza Baylor College of Medicine MC:335 Houston, TX 77030		
UT Austin	Jack Virostko Jack.Virostko@austin.utexas.edu Phone: 615-300-2265	4003 Avenue D Austin, TX 78751		
UCSF	Dr. Peder Larson Peder.Larson@ucsf.edu Phone: (415)514-4874	UCSF Mission Bay Genentech Hall, Rm 102 600 16th Street San Francisco, CA 94158		
UW	Paul E. Kinahan kinahan@uw.edu	Dr. Paul K. Kinahan 8002, 39th Ave NE Seattle, WA 98115		
Stanford	Contact? If interested to participate	Shipping Address?		


Pre-clinical Ice-Water Phantom:
Time-to-Equilibrium & Hold-Time
Without Insulation Jacket - Hold Time approx 1.5 hours
With Insulation Jacket - Hold Time approx 2.5 hours
Tempurature (Degrees C)
16
14
12
10
8
6
4
2
0
0
30
60
90
120
150
180
Time After Measurement Tube Insertion (minutes)