

**NCI Centers of Quantitative Imaging Excellence**

**MANUAL OF PROCEDURES**

**PART C**

**MRI TECHNICAL PROCEDURES**

## PART C

### MRI TECHNICAL PROCEDURES

#### 1. CQIE MRI QUALIFICATION

##### 1.1 Introduction

The purpose of this chapter is to provide detailed information regarding MR imaging and quality control activities required for CQIE qualification. For a full description of the qualification program refer to the CQIE Manual of Operating Procedures (MOP). The MR procedures and guidelines outlined in this document apply to all scanners to be qualified. Though qualification of only one MR scanner is required, sites are urged to qualify multiple scanners. With the purpose of advancing standardization and harmonization of imaging data in multicenter clinical trials, all scanners to be used for NCI clinical trial imaging should be qualified.

As explained in Part A, Section 1.2, of the CQIE MOP, the primary objective of the CQIE program is to establish a resource of 'trial ready' sites within the NCI Cancer Centers that are capable of conducting clinical trials in which there is an integral molecular and functional advanced imaging endpoint. In support of this objective, the CQIE program is designed to qualify sites to participate in advanced imaging trials which include the following MR imaging:

- Volumetric MR of the brain
- MR diffusion of the brain
- DCE-MRI of the body
- DCE-MRI of the brain

##### 1.2 Overview of MRI Procedures

MRI procedures for CQIE qualification include clinical test images for diffusion imaging, phantom tests with an ACR Accreditation MR phantom, phantom tests with the CQIE Body DCE-MRI phantom, and compliance with a standardized set of quality control measures.

Schedule of Procedures	Time Point			
	T0 Initial	T1 Annual 1	T2 Annual 2	T3 Annual 3
Clinical Test Case - MR Diffusion Brain	X	X	X	X
ACR Phantom Test	X	X	X	X
DCE-MR Phantom Test	X	X	X	X
Standardized Quality Control	X	X	X	X

##### 1.2.1 MRI System Requirements

CQIE qualification is intended for 1.5 Tesla MR Magnets; however, 3T imaging of the brain is permissible.

### 1.3 ACRIN Imaging Core Laboratory

The ACRIN Imaging Core Laboratory is headquartered within the American College of Radiology Clinical Research Center in Philadelphia. The role of the Imaging Core Lab is to (1) develop a manual of operations and training materials for the CQIE site qualification process (2) serve as a resource for technical and imaging protocol questions; (3) collect and archive qualification imaging data; and (4) provide qualitative and quantitative review of the qualification imaging data.

Should you have any questions or require additional information please consult the CQIE web site at <http://www.acrin.org/NCI-CQIE.aspx> or a member of the ACRIN CQIE project team by telephone or email:

PROJECT MANAGEMENT	IMAGING
<a href="mailto:CQIE-Manager@acr.org">CQIE-Manager@acr.org</a> Telephone: 215-940-8921 Fax: 215-717-0860	<a href="mailto:CQIE-MR-CT@acr.org">CQIE-MR-CT@acr.org</a> <a href="mailto:CQIE-PET@acr.org">CQIE-PET@acr.org</a>
<b>ACRIN hours of operation are 8:30 – 5:00 ET</b>	

## 2. QUALIFICATION IMAGING

### 2.1 Clinical Test Case – MR Diffusion

For initial and annual qualification assessment, sites will need to submit a diffusion-weighted MR series from a live subject or volunteer. The test case can be normal or abnormal. The test cases should be acquired within one month of the submission time point. Post-processed reconstructions of ADC maps are to be included with your submission. If eADC or FA maps are part of your institutional routine, these should also be included with your submission. Patient identifiers must be scrubbed from clinical images before transmission to ACRIN. Images must be submitted in DICOM format. The Test Cases will be qualitatively and quantitatively reviewed for overall technical image quality.

*Note: Contact the CQIE team at the ACRIN Imaging Core Lab if your scanner cannot reconstruct ADC maps.*

Minimum Diffusion Guidelines for All Vendors	
2D EPI	
Plane	Axial
B-Value	1000, 100
FOV	240 mm
Slice Thickness	5 mm
Gap	1.5
Matrix	128 x 128
Phase	A - P
Frequency	L - R

### 2.2 ACR MR Phantom Scans

For initial and annual qualification assessments, sites will need to perform phantom tests using an ACR MRI phantom—detailed phantom scanning instructions are provided as Appendix C1. If your site does not own an ACR-MR phantom, ACRIN will provide a phantom, on loan, or you may purchase your own. Additional information regarding the phantom loan procedures will be provided as part of the Site Qualification Plan, as needed. For purchasing information refer to the ACR web site or contact the ACRIN-CQIE project manager.

Phantom image data will be evaluated, per documented operating procedures, under the management of the Imaging Core Laboratory. Both a qualitative and quantitative review of the image data will be conducted. This review will include evaluation of geometric accuracy, high-contrast spatial resolution, slice thickness accuracy, slice position accuracy, image intensity uniformity, percent-signal ghosting, low-contrast object detectability, and compliance with image acquisition protocols.

### **2.3 DCE-MR Phantoms Scans**

For initial and annual qualification assessments, sites will need to perform phantom tests using a CQIE body DCE-MR phantom—detailed phantom scanning instructions are provided as Appendix C2. The DCE-MR phantom image data will be evaluated, per documented operating procedures, under the management of the Imaging Core Laboratory. Both a qualitative and quantitative review of the image data will be conducted. This review will include evaluation of T1 map error estimation, temporal resolution, image quality and compliance with image acquisition protocols.

### 3. STANDARDIZED QUALITY CONTROL

#### 3.1 Routine Quality Control

Quality control is an important function of image quality and patient safety and takes on even greater importance in multicenter quantitative imaging trials. The benefits of quality control include: verification of the operational integrity of the systems, consistent and high image quality, decreased chance of artifacts, early identification of potential problems, and consistent quantitative accuracy. As such, quality control of imaging equipment is fundamental to the goal of image standardization in imaging and therapy trials. In line with recommendations of the American College of Radiology, all CQIE sites are required to have a documented quality assurance program monitored by a qualified medical physicist/MR scientist. For additional guidance, please reference [ACR Technical Standard for Diagnostic Medical Physics Performance Monitoring of Magnetic Resonance Imaging Equipment](#) and [ACR Practice Guideline for Performing and Interpreting Magnetic Resonance Imaging](#).

##### 3.1.1 Acceptance Testing

The aim of acceptance testing is to verify that the equipment performs according to its specifications and clinical purpose. Acceptance testing should be performed according to manufacturer recommendations upon installation of imaging equipment and after major upgrades, before clinical use. The acceptance testing protocol should include an evaluation of all coils.

##### 3.1.2 Routine Quality Control Testing

Routine performance tests and preventive maintenance service are to be conducted according to performance measurements as outlined by the manufacturer and include regular testing procedures to insure proper operation on a daily basis. Federal standards require MR manufacturers to provide quality assurance testing instructions, recommended testing frequency, a QC phantom appropriate for the scanner and acceptable variations in parameter measurements. If any QC parameter being monitored falls outside of the control limits, corrective action should be taken.

#### 3.2 CQIE Standardized Quality Control

To address the need of imaging standardization in multicenter and/or quantitative imaging trials, CQIE sites are expected to comply with the quality control testing (and frequency) identified in 3.2.1 below. These tests may already be part of your existing QC program. If not, these tests are to be incorporated into your continuous quality control activities. Note that the standardized CQIE QC measures do not replace any QC measures required by law, accreditations, or those recommended by the manufacturer. Rather these QC measures were adopted for the CQIE program based on published recommendations by organizations and researchers involved in quantitative imaging and are intended to serve as a minimum QC standard. The purpose for establishing a standardized set of quality control activities is to help ensure the quantitative data generated are comparable within institutions, across institutions, and over time. However, due to the nature of advanced/experimental imaging, sites may be required to perform additional QC activities, or perform certain activities more frequently, to qualify for, or participate in, a given clinical trial. Compliance with CQIE QC

guidelines does not replace the responsibility for compliance with trial-specific requirements and vice-versa.

CQIE sites are expected to adhere to these quality control standards to maintain CQIE qualification. As with all QC testing, performance of these procedures should be documented in your QC log and archived. A MR QC Questionnaire will be required for the T2 and T3 qualification renewals. This questionnaire requires sites to attest to compliance with the CQIE standardized QC measures. Compliance with the CQIE QC standards is subject to audit.

### 3.2.1 Standardized QC Tests for MRI

Test	Minimum Frequency
Center Frequency	Weekly
Table Positioning	Weekly
Signal to Noise	Weekly
Artifact Analysis	Weekly
Geometric Accuracy	Weekly
High-Contrast Resolution	Weekly
Low-Contrast Resolution	Weekly
Magnetic Field Homogeneity	Quarterly
Slice Position Accuracy	Quarterly
Slice Thickness Accuracy	Quarterly
Radiofrequency Coil Checks	Annually

## 4. DATA SUBMISSION

### 4.1 Qualification Data

Submit the following data for each scanner to be qualified.

Time Point	Procedure	Data
T0-T3	Clinical Test Cases	<ul style="list-style-type: none"> <li>▪ Diffusion-weighted MR data set</li> <li>▪ ADC Maps</li> <li>▪ eADC or FA Maps (if applicable)</li> </ul>
T0-T3	ACR MR Phantom Tests	<ul style="list-style-type: none"> <li>▪ Scan 1: Modified ACR Protocol data set</li> <li>▪ Scan 2: 3D Volumetric data set</li> <li>▪ Scan 3: T1 Mapping for Brain DCE-MRI data set</li> <li>▪ Scan 4: Brain DCE-MRI data set</li> </ul>
T0-T3	Body DCE-MR Phantom Tests	<ul style="list-style-type: none"> <li>▪ Scan 1: T1 Mapping for Body DCE-MRI data set</li> <li>▪ Scan 2: Body DCE-MRI data set</li> <li>▪ Scan 3: Coil Maps</li> </ul>
T1-T3	Image Transmittal Worksheet	<ul style="list-style-type: none"> <li>▪ Scanner specifications</li> <li>▪ Notification to ACRIN of data submission</li> </ul>
T2-T3	Quality Control	<ul style="list-style-type: none"> <li>▪ Quality Control Questionnaire</li> </ul>

#### Clinical Test Cases

Images must be submitted in DICOM format. Patient identifiers must be scrubbed from clinical images before transmission to ACRIN.

#### Data Submission

Images must be submitted in DICOM format. Image data should be transmitted to ACRIN electronically via secure file transfer protocol (FTP). Download and installation instructions for FTP setup are provided in Part A of this MOP, Appendix A2. An Image Transmittal Worksheet (ITW) should accompany each image submission. Refer to the CQIE web site, <http://www.acrin.org/NCI-CQIE.aspx>, for all qualification materials, including the ITW.

If necessary images can be sent on CD-ROM. Sites submitting images via CD should mail the package, including a copy of the ITW, to the ACRIN Imaging Core Lab at the address below. Method of shipment should include package tracking.

ACRIN Imaging Core Lab, # CQIE-MR  
American College of Radiology  
1818 Market Street, Suite 1600  
Philadelphia, PA 19103



## 5. References

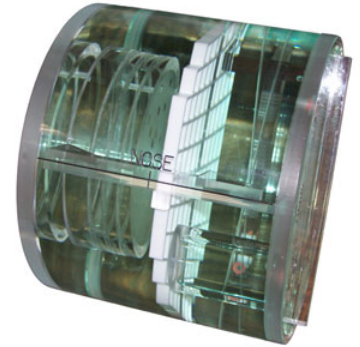
- American College of Radiology. MRI Quality Control Manual, 2004
- American College of Radiology. [ACR Technical Standard for Diagnostic Medical Physics Performance Monitoring of Magnetic Resonance Imaging Equipment](#), 2009.
- American College of Radiology. [ACR Practice Guideline for Performing and Interpreting Magnetic Resonance Imaging](#), 2006.
- [Imaging Working Group \(IWG\)](#), Clinical Translational Science Awards (CTSA).
- [Quantitative Imaging Biomarkers Alliance \(QIBA\)](#), Radiological Society of North America (RSNA).

## MR PHANTOM TEST INSTRUCTIONS: ACR MR PHANTOM

This document provides detailed instructions for performing the ACR Accreditation MR phantom tests. Though based on the ACR MR Accreditation testing, modifications were made for purpose of CQIE qualification. If your site does not own an ACR-MR phantom, ACRIN will provide a phantom, on loan, or you may purchase your own. Additional information regarding the phantom loan procedures will be included in your Site Qualification Plan. For purchasing information refer to the ACR web site.

### 1. ACR Accreditation MR Phantom

The ACR MRI phantom is a short, hollow cylinder of acrylic plastic closed at both ends. The inside length is 148 mm; the inside diameter is 190 mm. It is filled with a solution of nickel chloride and sodium chloride: 10 mM NiCl<sub>2</sub> and 75mM NaCl. The outside of the phantom has the words “NOSE” and “CHIN” etched into it as an aid to orienting the phantom for scanning, as if it were a head. Inside the phantom are several structures designed to facilitate a variety of tests of scanner performance.



*ACR MR Phantom  
Figure 1*

### 2. Test Preparation and Set Up

Please read the following instructions in full before scanning the phantom. The ACR MR phantom will be used for the following phantom scans:

- Phantom Sequence 1: ACR Protocol
- Phantom Sequence 2: CQIE 3D Volumetric Protocol
- Phantom Sequence 3: CQIE T1 Mapping Series for Brain DCE-MRI
- Phantom Sequence 4: CQIE Brain DCE-MRI Protocol

The position and alignment of the ACR MR phantom is the same for all 4 of the phantom scans in this section. The phantom should be scanned in the head coil with the cylindrical phantom aligned as a head would be in the coil. Transaxial slices should result in circular cross-sections of the phantom. The phantom should be positioned so that the word “Nose” is where the nose would be for a standard head study and the word “Chin” is where the chin would be located in a standard head study. The center of the phantom (the dark notch on the side of the phantom) should be placed in the center of the head coil and aligned with the positioning indicator light so that it will be in the isocenter of the scanner. Once grossly positioned, it is then necessary to “fine tune” the position of the phantom along all three axes. For this, you will need to use a non-metallic bubble level.

Place the level along the top of the phantom running in and out of the scanner (along the z-axis) to ensure that the phantom is horizontal. Place a gauze pad under either end of the phantom to level the phantom horizontally. Next, place the level on top of the plastic bar at the chin surface, rotating the phantom so that the plastic bar is horizontal. With the phantom then clamped or wedged inside the head coil, check to see that the sagittal laser alignment light is parallel to the line running along the “nose” surface of the phantom. (To see the laser light reflection, it may be necessary to place a piece of white paper on top of the phantom.) After each position adjustment, recheck that the top of the phantom and the

**MR PHANTOM TEST INSTRUCTIONS: ACR MR PHANTOM**

chin bar are still horizontal. In addition, you will want to confirm that the axial alignment light is parallel to the superior end of the geometric distortion grid (array of squares) as shown by the arrows in Figure 2.

After the phantom has been moved into the center of the magnet, verify its positioning by performing sagittal and, if desired, coronal plane localizer scans, until correct. (Please note, some systems require that a weight be entered in order to scan the phantom. The ACR recommends that your site enter a weight of 200 lbs.) Once correctly aligned, the phantom should be kept in the same position during the entire series of scans.



Figure 2

**3. Phantom Scan**

If your site is performing these tests for the first time you will need to build the acquisition and save it to your scanner's protocol menu, this may require special user permissions. When setting up the scans, enter your institution name in the patient name field (see example below).

Patient Name: CQIE Name of Your Cancer Center (ex. ACRIN Cancer Center)

**Phantom Sequence 1: Modified ACR Protocol**

**SERIES # 1:** A sagittal locator sequence should be acquired with the acquisition parameters listed below as Series 1. The sagittal locator scan should result in an image similar to Figure 3 on the following page. If the pairs of 45° crossed wedges are not visible in the scan, the phantom must be repositioned and rescanned. A horizontal line used for slice prescription (see Figure 4) should be parallel to the low contrast disks located at the top of Figure 3 or Figure 4. If not, the phantom must be repositioned. If using a multi-channel head coil, pre-scan normalization (e.g. PURE, CLEAR) must be disabled.

Modified ACR Protocol	Pulse Sequence	TR (ms)	TE (ms)	FOV (mm)	# of Slices	Slice Thickness (mm)	Slice Gap (mm)	NEX	Matrix	Scan Time (min:sec)	Pre-Scan Normalization
S-1 Sagittal Locator	Spin Echo	200	20	256 (25 cm)	1	20 mm	N/A	1	256 x 256	00:56	OFF
S-2 Axial T1	Spin Echo	500	20	256	11	5 mm	5	1	256 x 256	02:16	OFF
S-3 Axial T2 Double-Echo	Spin Echo	2000	20/80	256	11	5 mm	5	1	256 x 256	08:56	OFF
S-4 Axial T1 (multi-channel coils only)	Spin Echo	500	20	256	11	5 mm	5	1	256 x 256	02:16	ON

*Note: Do not use post-process image leveling filters for image intensity correction (e.g. SCIC)*

**MR PHANTOM TEST INSTRUCTIONS: ACR MR PHANTOM**

**SERIES # 2-3:** Acquisitions 2 and 3 are transaxial spin echo pulse sequences acquired with identical spatial parameters: 5mm slice thickness, 5 mm gap, 25 cm FOV, 256 x 256 matrix. At least 11 slices should be obtained, aligned using graphic prescription from the sagittal locator as shown in Figure 4 (Note: This is the preferred method for slice positioning). The center of slice #1 should be aligned with the vertex of the lower set of crossed wedges (visible on the lower left in Figures 3 and 4) and through the center of the dark chemical shift and resolution insert (visible on the lower right). Slice #1 should result in a transaxial image that looks like Figure 5. The centers of slices #8–11 should align with the four low-contrast discs shown toward the top in Figures 3 and 4. Your axial slices must be positioned as shown in Figure 4 in order for your images to be acceptable for evaluation. If using a multi-channel head coil, pre-scan normalization must be disabled.

**SERIES # 4 (Multi-Channel Head Coils):** This acquisition should be performed only if using a multi-channel head coil. The acquisition is a transaxial pulse sequence acquired with identical spatial parameters as Series # 2 and 3 but with pre-scan normalization enabled – Series #1-3 should have been performed with pre-scan normalization disabled. Calibration scans needed for PURE can be performed at any point prior to Series 4, as needed.

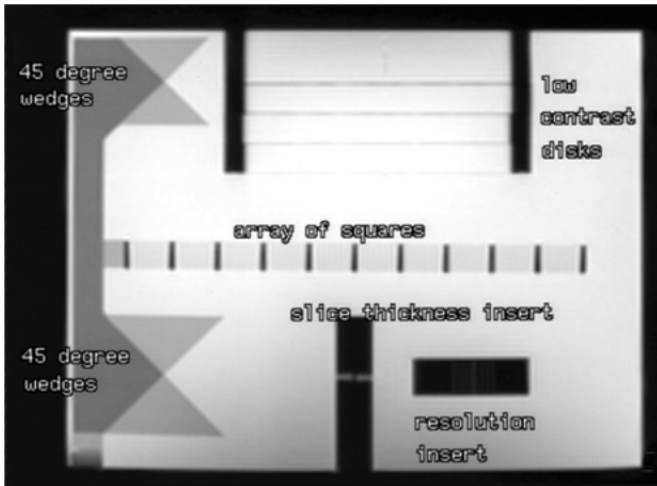


Figure 3

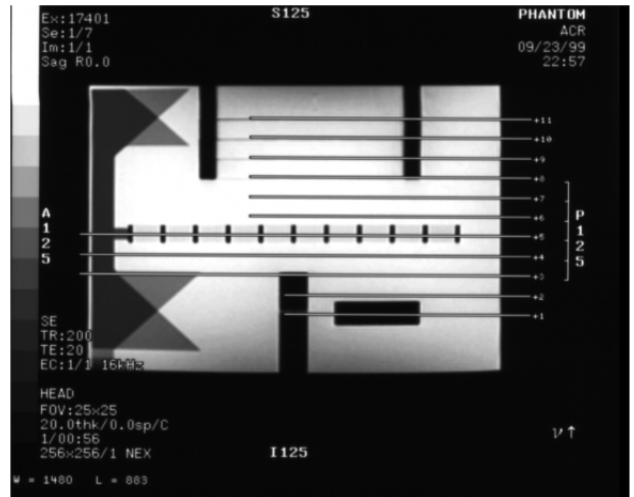


Figure 4

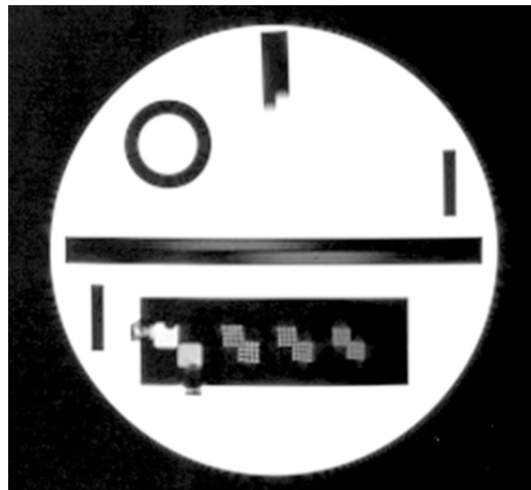


Figure 5

**MR PHANTOM TEST INSTRUCTIONS: ACR MR PHANTOM**

***Phantom Sequence 2: CQIE Sagittal 3D Volumetric Protocol***

Maintain the positioning of the ACR MR phantom as described above. Using slice 5 of the Axial T1 series, prescribe a sagittal 3D volumetric slab using a T1 weighted, spoiled gradient echo with an Inversion Recovery-preparatory pulse. The volume should be prescribed to sufficiently cover the entire phantom in the sagittal plane.

3D Volumetric Protocol	Plane	TR (ms)	TE (min)	T1	Flip Angle	FOV (mm)	Phase FOV	Slice Thickness	Gap	Matrix	Phase	Freq	NSA
Siemens 3D MPRAGE	Sagittal	2500 - 2800	3.5 min.	1100	7°	256 (25 cm)	100%	1.3 mm	None	256 x 256	A - P	S - I	1 Minimum
Philips 3D TFE	Sagittal	Minimum	4 min.	870	8°	256	100%	1.3 mm	None	256 x 256	A - P	S - I	1 Minimum
GE IR-FSPGR	Sagittal	-10	Min. Full	450	20°	256	100%	1.3 mm	None	256 x 256	A - P	S - I	1 Minimum

***Phantom Sequence 3 & 4: Brain DCE-MRI Protocol***

Dynamic contrast-enhanced (DCE) MRI protocols are performed using a T1-weighted, 3D multi-phase spoiled gradient echo perfusion technique. Although no contrast media will be used for the phantom tests, when performed clinically on patients, the dynamic contrast-enhanced series is preceded by a series of non-contrast, single-phase acquisitions, each performed at a different flip angle. The non-contrast series make up the “T1 Maps;” these are essential to understanding the inherent T1 of the tissue and mapping the B1 magnetic field before the introduction of contrast media to the tumor and surrounding vasculature. The required flip angles are shown in the chart below. Note that the lowest flip angle must be 5 degrees or less; a 2 degree flip angle is ideal.

Brain DCE-MRI Protocol	Plane	TR (ms)	TE (ms)	Flip Angles	FOV (mm)	Phase FOV	Thick	Gap	Matrix	Phase	NEX (NSA)	Time per Phase	Total Scan Time
T1 Maps 3D (5 series total)	Axial	3.0-6.5	Minimum	30, 20, 15, 10, ≤5°	256	75 - 100%	5 mm	None	256 x 128	R - L	1 - 2 <sup>1</sup>	Single Acq	Single Acq
DCE 3D	Axial	3.0-6.5	Minimum	20 - 35°	256	75 - 100%	5 mm	None	256 x 128	R - L	1	3 - 8 seconds	> 6 minutes

<sup>1</sup> Perform the T1 maps with 2 NEX if it is permitted by your system with the use of parallel imaging

Suggested imaging parameters are provided (above) to assist in building your DCE-MRI Brain protocol. The parameters for conducting DCE-MRI, and indeed many dynamic

## MR PHANTOM TEST INSTRUCTIONS: ACR MR PHANTOM

protocols of a specified spatial resolution, can vary greatly between scanner vendors, models, hardware, software versions and field strengths. Understanding these challenges is essential to understanding DCE-MRI implementation. It is for this reason that vendor and platform-specific parameters are not explicitly provided for this exercise. Rather, guidelines are provided and the *spatial resolution* requirements (matrix, slice thickness, field of view, etc.) for the DCE series and the associated T1 maps which precede it are required to fall within a provided *temporal resolution* limit for the given anatomical area (e.g. eight seconds or less per phase in the brain; ten seconds or less in the body per phase or “measurement”). The parameters in the shaded boxes in the table above will vary depending on the capabilities of your scanner. The remaining areas represent the required minimum settings for CQIE qualification for DCE-MRI of the brain.

### DCE-MRI Brain Pre-Scan Notes:

- Scan the DCE-MRI protocol using the same coil and phantom set-up as in Phantom Sequences 1 & 2 above.
- For all series, do not use normalization or intensity correction filters such as CLEAR, SCIC or PURE.
- The slice locations and positioning for the T1 mapping and the dynamic series must be identical.
- The TR and TE for all six scan series (5 T1 maps plus a dynamic series) should be identical. For GE systems, reduce Turbo Factor to 1 or 0 if TR and TE do not match across series. If you still have difficulty with TR & TE, contact the CQIE technical team.
- If magnets and multichannel head coils are available to perform parallel imaging (e.g. ASSET, SENSE, IPAT), speed factors of 2 can be used. Do not use higher speed factors. If parallel imaging techniques *are* used, identical parallel imaging techniques must be used on all series.
- The total slab thickness must yield a 6 cm slab of **reconstructed** coverage. Therefore, a minimum of 12 slices must be reconstructed at 5mm. A minimum of 20% slice oversampling is recommended to reduce z-axis overwrap into the evaluable volume.
- Images on the dynamic run should be acquired as a **3D FSPGR/FLASH true axial at a 20-35 degree flip angle**; do not prescribe slabs as an oblique.
- Pre-scan calibration is completed for the first T1 mapping series only and is not repeated until after the dynamic series is completed.
- Perform a three-plane localizer per your institutional routine for a brain study, or you may use the localizer suggested in section one for the ACR series. (This localizer is not evaluated for qualification.)

### ***Phantom Sequence 3: T1 Mapping Series for DCE-MRI Brain***

- The five T1 mapping series, as well as the dynamic DCE series, are to be prescribed identically in the axial plane with the first slice being the inferior-most slice.
- Using the midline sagittal image, prescribe the first axial T1 mapping series axially with the center of the volume centered roughly to the center of the phantom (see Figure 6).

**MR PHANTOM TEST INSTRUCTIONS: ACR MR PHANTOM**

- Copy this slab prescription to the remaining T1 maps and the dynamic series.
- Run the T1 maps:
  - 30 degrees Pre-scan per usual routine
  - 20 degrees No pre-scan
  - 15 degrees No pre-scan
  - 10 degrees No pre-scan
  - 5 degrees No pre-scan



Figure 6

***Phantom Sequence 4: DCE-MRI Brain Series***

- Run the DCE dynamic series; no pre-scan.

The temporal resolution (or time per phase/measurement) of the DCE dynamic series must be less than 8 seconds, and ideally 6 seconds or less. The total imaging time for the dynamic series must be at least 6 minutes. This amounts to 45 to 120 phases, depending upon the acquisition time per phase. The total number of images acquired should be 540 to 1,920 depending on the number of images per slab and the number of phases.

Example: Given a scan time of 5 seconds per phase/measurement...

6 minutes = 360 seconds
360 seconds / 5 seconds = 72 phases
72 phases x 12 slices per phase = 864 slices

## MR PHANTOM TEST INSTRUCTIONS: BODY DCE-MR PHANTOM

This document provides information about the CQIE Body DCE-MR phantom tests. The CQIE Body DCE-MRI phantom is not currently a commercially available phantom (see figure 1). The phantom contains 23 vials of varying concentrations of gadolinium and other solutions. The vials are surrounded by a loading solution consisting of a bath of distilled water. Note that the water level in the phantom will not appear full, this is normal. The phantom will be provided by ACRIN to all sites for baseline and annual qualification testing. Please read the following instructions in full before conducting your phantom tests.

### 1. Body DCE-MRI Phantom

To reduce variance, a standardized imaging phantom designed specifically for body DCE-MRI will be used. ACRIN will conduct both a qualitative and quantitative review of the image data. This review will include evaluation of T1 map error estimation, temporal resolution, image quality and compliance with image acquisition protocols (via check of DICOM metadata).

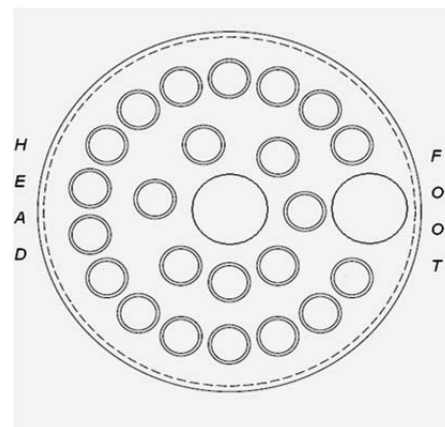
### 2. Phantom Set Up

If your site is performing this test for the first time you may want to build your CQIE Body DCE-MRI protocol before positioning the phantom, see Section 3 (below) for detailed instructions.

- **Coronal acquisition plane.**
- Use the surface array coil per your institutional routine for abdominal imaging (i.e. torso-array).
- Place the CQIE Body DCE-MRI phantom in the center of the table, on top of the posterior elements of the torso-array coil with the vial lids facing upwards. The phantom should be positioned over the elements typically selected for a liver study. Assuming a feet-first entry into the bore, the large translucent lid on the outer diameter should represent the “foot” of the phantom (as illustrated in Figures 2 and 3).
- Add the anterior torso array coil elements to the top (lid-side) of the phantom.
- Pad either side of the phantom as necessary to ensure ideal alignment of the coil elements about the phantom.
- Landmark to the center of the phantom.

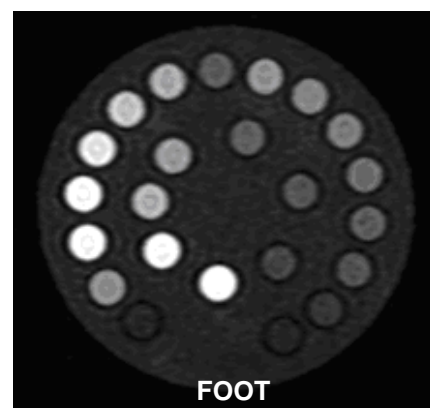


Figure 1



Entry into magnet bore →

Figure 2



Final image orientation

Figure 3



## MR PHANTOM TEST INSTRUCTIONS: BODY DCE-MR PHANTOM

### 3. Test Preparation – The CQIE Body DCE-MRI Protocol

If your site is performing this test for the first time you will need to build the acquisition protocol and save it to your scanner's protocol menu, this may require special user permissions. The parameters for conducting DCE-MRI can vary greatly between scanner vendors, models, software versions and field strengths. Understanding these challenges is essential to understanding DCE-MRI imaging. It is for this reason that vendor and platform-specific parameters are not explicitly provided. The **CQIE Body DCE-MRI Protocol Worksheet (Appendix C3)** will assist you in optimizing a scanner-specific protocol to achieve the minimum required temporal and spatial resolution.

#### *Dynamic Series*

- Use the Body DCE-MRI Protocol Worksheet (Appendix C3) to define the acquisition parameters for a basic dynamic series.
- Add a CQIE Body DCE-MRI Phantom protocol to your scanner's protocol menu. Enter/save the technical parameters for the basic dynamic series, based on the output of the above referenced protocol worksheet, and label as "Dynamic Series."

#### *Single-Phase T1 Mapping Series*

- Copy and paste the parameters from the "Dynamic Series" for 30 degrees, 15 degrees and 5 degrees. Place these series to run immediately before the Dynamic Series.
- Rename each of the three series as "T1 Map – X" (where 'x' is the flip angle).
- Change the number of phases/measurements for each of the three T1 Maps to 1 (for GE systems, remove the multi-phase option) – change this only for the three T1 Maps.
- Change the NEX/NSA for each of the T1 Maps to 3 – again, change this only for the three T1 Maps. This will increase the scan time for the T1 Maps (this is normal).

#### *Coil Map Series*

- Copy the "T1 Map 15 degrees" series twice and place these two series immediately after the dynamic scan.
- Rename the first of these two series "Body Coil Map" and set the coil to body.
- Rename the second of these two series "Array Coil Map" and confirm that the torso array coil is selected as the receive coil.
- In all, your Body DCE-MRI protocol will have the following series prepared, in the order shown, to scan the CQIE DCE-MRI Body Phantom:

3 plane localizer			
T1 Map 30	30 degrees	Tuned	Pre-scan
T1 Map 15	15 degrees	Not Tuned	No Pre-scan
T1 Map 5	5 degrees	Not Tuned	No Pre-scan
Dynamic Series	30 degrees	Not Tuned	No Pre-scan
CQIE Body Coil Map	15 degrees	Tuned	Pre-scan
CQIE Array Coil Map	15 degrees	Not Tuned	No Pre-scan

## MR PHANTOM TEST INSTRUCTIONS: BODY DCE-MR PHANTOM

### 4. Phantom Scans

When setting up the scans, enter your institution name in the patient name field (see example below).

Patient Name: CQIE *Name of Your Cancer Center* (ex. ACRIN Cancer Center)

#### *Pre-Scan Notes*

- Do not use normalization or intensity correction filters such as CLEAR, SCIC or PURE for any of the series.
- The slice locations and positioning for the T1 mapping and the dynamic series must be identical.
- The TR and TE for all six scan series (5 T1 maps plus a dynamic series) should be identical. For GE systems, reduce Turbo Factor to 1 or 0 if TR and TE do not match across series. If you still have difficulty with TR & TE, particularly at 30 degrees, contact the CQIE technical team.

#### *Phantom Scan 1: T1 Maps for Body DCE-MRI*

- Run a conventional 3 plane localizer to identify the phantom.
- Prescribe the 3D slab as a straight coronal acquisition centered to the phantoms.
- Run the T1 Map at 30 degrees, prescribing the 3D slab in the oblique/coronal plane through the center of the phantom, centered in all 3 planes (pre-scan as usual)
- Run the next T1 Map at 15 degrees, copying the position of the 3D slab from the previous series (no pre-scan).
- Run the next T1 Map at 5 degrees, copying the position of the 3D slab from the previous series (no pre-scan).

#### *Phantom Scan 2: Dynamic Series for Body DCE-MRI*

- Run the Dynamic Series at 30 degrees, again copying the position of the 3D slab from the previous series (no pre-scan). This is a multi-phase series – enable multi-phase (on GE systems) and increase the number of phases (or measurements) until the scan time is six minutes.

*Example: If your scan time is 8 seconds per phase/measurement...*

6 minutes = 360 seconds

360 seconds / 8 seconds = 45 phases

On an actual patient, contrast injection would occur after 10 baseline phases. For example, if your scan time is 8 seconds per phase/measurement, you would inject after 80 seconds. Typical injection rates are 3-5cc/second at 0.1mmol/kg followed by a 20cc saline flush at the same rate.

#### *Phantom Scan 3: Coil Maps for Body DCE-MRI*

- Run the Body Coil Map; ensure the integrated Body Coil is selected (pre-scan as usual).
- Run the Array Coil Map; ensure that the Torso Array Coil is selected (no pre-scan)

**BODY DCE-MRI PROTOCOL WORKSHEET**

**1. Enter the following scan parameters into your system:**






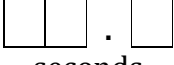
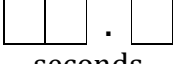
<b>Body DCE-MRI Imaging Protocol</b>		GE: 3D Fast SPGR Siemens: 3D FLASH Philips: 3D TFE
Plane	Oblique (coronal)	
TE	minimum	
Frequency FOV	40 cm	
Flip Angles	30 degrees	
Phase FOV	40 cm (100%)	
Slice Thickness	6 mm	
Frequency Matrix	256	
Phase Matrix	128	
Number of Locs (reconstructed)	12	
Slice Oversampling (Siemens)	25% (if applicable)	
Pixel Interpolation	Off	
Spatial Saturation Bands	Anterior and Posterior	
Slice Interpolation	Off	
Fat Saturation	Off	
Phase Direction	L - R	
ASSET / IPAT / Parallel Imaging	Off	
BW	62.5 kHz (GE) 250 Hz/px (Siemens/Philips)	
TR	Minimum	
Number of Acquisitions (NEX/NSA)	1 (do not use ZIP512, ZIPx2, or IRprep)	
Delay before Acquisition (GE CV4)	0	
Turbo Factor (GE CV)	0	
Slice Resolution	100%	

**2. Based on the parameters above, record the scan time for the basic series:**

.  seconds

- **If the scan time is less than 10 seconds → STOP.** These parameters will be the basis for your dynamic, multi-phase series. Go back to the phantom scan instructions.
- **If the scan time is longer than 10 seconds → Go to page 2,** proceed step-by-step, in order, *until the scan time is less than 10 seconds per phase.* In each step, indicate the new time. If the modification provided is not possible, indicate using the check box and re-enter the time from the previous step.

**BODY DCE-MRI PROTOCOL WORKSHEET**

<b>Acquisition Parameters Adjustment</b>		<b>Cannot Perform</b>	<b>Can Perform</b> New series time
3.1	Increase BW to (a) or (b) then reset TR and TE to new minimum values (a.) GE = 83.3 kHz (b.) Philips or Siemens = 375 Hz/px	<input type="checkbox"/>	 seconds
3.2	Change # locations to 8	<input type="checkbox"/>	 seconds
3.3	Change to 90% partial FOV (36 cm phase FOV)	<input type="checkbox"/>	 seconds
3.4	Increase FOV to 42cm and change partial FOV to 80% (L/R phase FOV=35.7 cm)	<input type="checkbox"/>	 seconds
3.5	Remove anterior and posterior saturation bands	<input type="checkbox"/>	 seconds
3.6	Change NEX to equal 0.75 (or 6/8 partial fourier)	<input type="checkbox"/>	 seconds
3.7	Turn on parallel imaging (acceleration factor of 2)	<input type="checkbox"/>	 seconds