

# qCal-MR™ Diffusion Phantom Protocols for Scanner Set-Up

The CMRI Diffusion Phantom Protocol implements the analysis described in the the **QIBA DWI Profile, dated Feb 5, 2019**, with the exception that it is intended to be used with the Diffusion Phantom, Model 128 at room temperature.

The protocol expects to receive four DWI scans on the phantom, all acquired in the same conditions and using the same parameters, and all belonging to the same study. Additionally, a  $T_1$ -weighted image should be acquired before and after the DWI scans to allow for temperature measurement if the included LC-thermometer is to be used.

For specific guidance on phantom preparation, image acquisition, and expected scanner parameters, please review **QIBA Profile Conformance Testing Supplement #1, sections II and III**.

## Liquid Crystal (LC) Thermometer Sequence

### Requirements

Across all series, there shall be a **single value** for **field of view mm**.

Across all series, there shall be a **single value** for **pixel bandwidth**.

Across all series, there shall be a **single value** for **repetition time**.

Across all series, there shall be a **single value** for **b value**.

Across all series, there shall be a **single value** for **echo time**.

Across all series, there shall be a **single value** for **inversion time**.

Across all series, there shall be a **single value** for **sequence**.

**Fat suppression** shall be **False**.

**Repetition time** shall be **at most 25**.

Across all series, there shall be a **single value** for **flip angle**.

### Expected Parameters

**B value** should be **0**.

**Flip angle** should be between **10 and 20**.

**Repetition time** should be between **4 and 10**.

**Slice thickness** should be **at most 4**.

# DWI SNR, within-subject Coefficient of Variation (wCV), Repeatability Coefficient (RC), Random Error Sequences

## Requirements

Across all series, there shall be a **single value** for **field of view mm**.

Across all series, there shall be a **single value** for **pixel bandwidth**.

Across all series, there shall be a **single value** for **repetition time**.

Across all series, there shall be a **single value** for **flip angle**.

Across all series, there shall be a **single value** for **echo time**.

Across all series, there shall be a **single value** for **fat suppression**.

Across all series, there shall be a **single value** for **sequence**.

Across all series, there shall be **at least 2 distinct values** for **b value**.

**Repetition time** shall be at least **2000**.

All series must have the **same value** for **b value**.

**Number of frames (series \* temporal positions)** shall be **at least 2**.

## Expected Parameters

**Flip angle** should be **90**.

**Fat suppression** should be **False**.

**B value** should be **0, 500, 1000, 1500, 2000**.

**Number of frames (series \* temporal positions)** should be **at least 4**.

DWI Images should be trace DWI images or be a complete set of directional DWI images that can be used to produce an anisotropic image.

**All series** should be in **immediate succession**.

**Rep tim msec** should be between **7000 and 10000**.

**Echo time** should be between **50 and 150**.

**Number of averages** should be **2**.

**Pixel bandwidth** should be between **1000 and 2500**.

**Acquisition matrix freq dim** should be between **128 and 160**.

**Acquisition matrix phase dim** should be between **128 and 160**.

**Slice thickness** should be between **3.8 and 4.2**.

**Spacing between slices mm** should be between **4 and 6**.

**In plane phase encoding direction** should be any of ('COL', 'COLUMN').

**Parallel reduction factor** should be between **1.9 and 2.1**.

**Magnetic field strength** should be between **1.5 and 3**.

# ADC Sequence

## Requirements

Across all series, there shall be a **single value** for **field of view** mm.

Across all series, there shall be a **single value** for **pixel bandwidth**.

Number of **frames (series \* temporal positions)** shall be **1**.

Across all series, there shall be **at least 2 distinct values** for **b value**.

Across all series, there shall be a **single value** for **repetition time**.

Across all series, there shall be a **single value** for **echo time**.

## Expected Parameters

**B value** should be **0, 500, 1000, 1500, 2000**.

**Fat suppression** should be **False**.

**Flip angle** should be **90**.

DWI Images should be trace DWI images or be a complete set of directional DWI images that can be used to produce an anisotropic image.

**Rep tim msec** should be between **7000 and 10000**.

**Echo time** should be between **50 and 150**.

**Number of averages** should be **2**.

**Pixel bandwidth** should be between **1000 and 2500**.

**Acquisition matrix freq dim** should be between **128 and 160**.

**Acquisition matrix phase dim** should be between **128 and 160**.

**Slice thickness** should be between **3.8 and 4.2**.

**Spacing between slices mm** should be between **4 and 6**.

**In plane phase encoding direction** should be any of ('COL', 'COLUMN').

**Parallel reduction factor** should be between **1.9 and 2.1**.

**Magnetic field strength** should be between **1.5 and 3**.

## ADC qCal-MR™ Calculation Info

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ADC is calculated using the following formula:

$$S_{B_x} = S_{B_0} * e^{(-B_x * ADC)}$$

Where:

- ›  $S_{B_x}$  is the value of the pixel in the DWI image with B-value  $B_x$
- ›  $S_{B_0}$  is the value of the pixel in the DWI image with B-value 0
- › When more than two B-values are available, the ADC value is determined using a least squares fit.
- › B-Value Dependence is calculated per the guidelines in QIBA Profile: Diffusion-Weighted Magnetic Resonance Imaging dated 2019-Dec-20, in section 4.3.

$$\text{ADC B-Value Dependence} = 100\% * \left\| \frac{\text{ADC}_{b_{\min}b_j} - \text{ADC}_{b_{\min}b_i}}{\text{ADC}_{b_{\min}b_i}} \right\|$$

B-value dependence can only be calculated for series with 3 or more b-values. The b-value dependence is calculated for all pairs of b-values, and the maximum dependence is reported for each VOI.

## DWI SNR qCal-MR™ Calculation Info

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The signal to noise ratio is calculated per the guidelines in QIBA Profile: Diffusion-Weighted Magnetic Resonance Imaging dated 2019-Dec-20, in section 4.2.

DWI SNR, or  $\text{SNR}_n$ , is defined as:

- › Select the scan from each series with b value 0
- › Define a signal image as the mean value of each pixel value across the b=0 scans
- › Define a noise image as the standard deviation of each pixel value across the b=0 scans
- › DWI SNR, then, is the ratio of the ROI mean value from the signal image to the ROI mean value from the noise image
- › Repeat this procedure for other b values

Note, that the displayed volume is the ratio of the signal image to the noise image per pixel (the signal-to-fluctuation-noise-ratio image). This is meant for visualization purposes only, and does not correspond exactly to the SNR calculations for each ROI.

## wCV qCal-MR™ Calculation Info

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The within-subject Coefficient of Variation (wCV) is calculated per the guidelines in QIBA Profile: Diffusion-Weighted Magnetic Resonance Imaging dated 2019-Dec-20, in section 4.1.

wCV is defined as:

- › Calculate an ADC map for each series included in the wCV calculation.
- › For each VOI, calculate the mean ADC value in each series.
- › Determine the mean,  $\mu$ , and the standard deviation,  $\sigma_w$ , of the value calculated for each VOI across the different series
- › wCV, then, is  $100\% * \sigma_w / \mu$

Note, that the displayed volume is the ratio of the std deviation to the mean, calculated per pixel. This is meant for visualization purposes only, and does not correspond exactly to the wCV calculations for each ROI.

## Repeatability Coefficient qCal-MR™ Calculation Info

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The Repeatability Coefficient is calculated per the guidelines in QIBA Profile: Diffusion-Weighted Magnetic Resonance Imaging dated 2019-Dec-20, in section 4.1.

RC is defined as:

- › Calculate an ADC map for each series included in the RC calculation.
- › For each VOI, calculate the mean ADC value in each series.
- › Determine the standard deviation,  $\sigma_w$ , of the value calculated for each VOI across the different series
- › RC, then, is  $2.77 * \sigma_w$

Note, that the displayed volume is  $2.77 * \text{std deviation}$ , calculated per pixel.

## Random Error qCal-MR™ Calculation Info

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Random Error is defined as:

- › Calculate an ADC map for each series included in the Random Error calculation.
- › Define a signal image as the mean value of each pixel value across the ADC maps
- › Define a noise image as the standard deviation of each pixel value across the ADC maps
- › Random Error, then, is the ratio of the ROI mean value from the noise image to the ROI mean value from the signal image

Note, that the displayed volume is the ratio of the noise image to the signal image per pixel. This is meant for visualization purposes only, and does not correspond exactly to the random error calculations for each ROI.

## LC Thermometer qCal-MR™ Calculation Info

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Identify the location of the LC thermometer and use the phase of the vials to determine temperature