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SML-ACR MRI Phantom

1. Product Introduction and Structure

A.1. SML-ACR Phantom

The SML-ACR MRI phantom is approved by the American College of Radiology (ACR) certification program. It is a cylinder with a diameter of 4.5 inches (11.43 cm) and a length of 4.5 inches (11.43 cm). The internal structure is designed to improve the scanning performance of each tested part, and the labels "NOSE" and "CHIN" are printed on the outside of the phantom to indicate the scanning direction.

Unit: centimeter

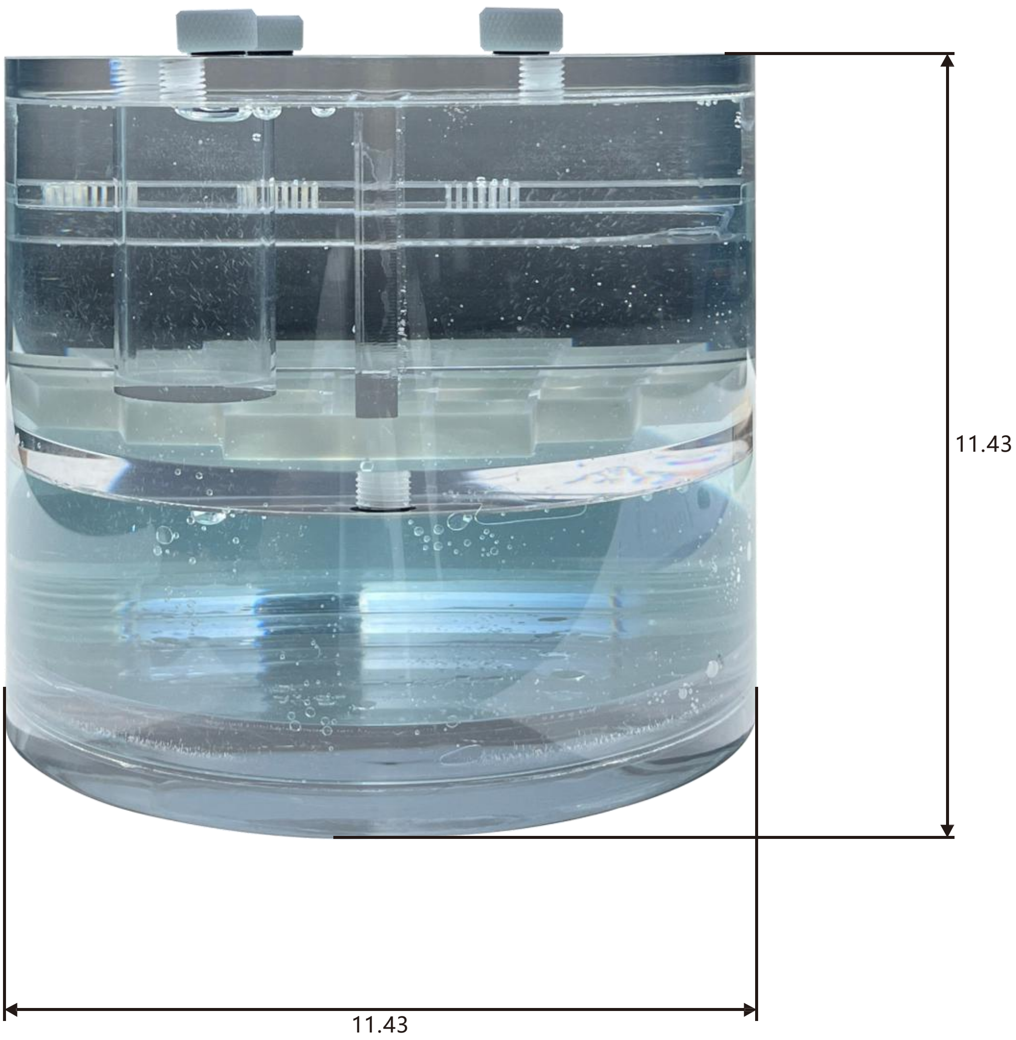


Figure A.1 Structural Diagram of the ACR MRI Phantom

A.2. Phantom Specifications

- Functions:

  Suitable for the evaluation of imaging performance of small coils (limb coils, breast coils). Including: geometric accuracy, spatial resolution, slice thickness and positioning, low-contrast resolution, image uniformity, signal-to-noise ratio, artifact detection, slice offset, water-fat shift.。
- Technical specifications:

  Diameter: 4.5 inches (approximately 11.43 centimeters)

  Cylinder length: 4.5 inches (approximately 11.43 centimeters).

  Total length (including mounting bar): 5.375 inches (approximately 13.65 centimeters)
- Functional inserts:

  It shall include resolution inserts, slice thickness inserts, geometric distortion inserts, low-contrast inserts, and the like.
- Other accessories:

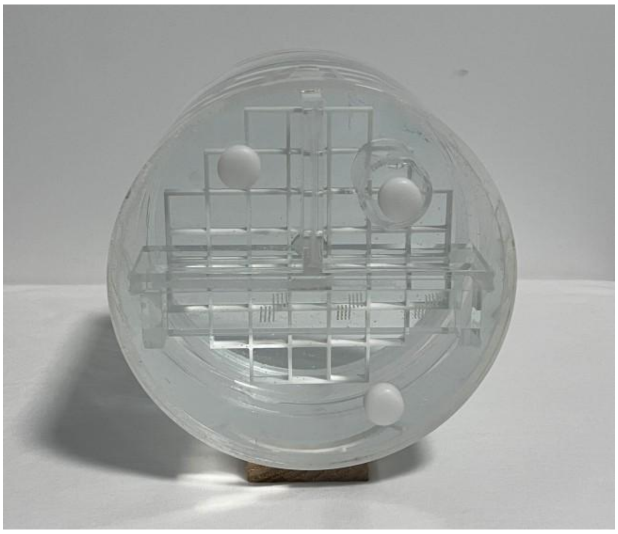
  All-plastic spirit level: Used to ensure the levelness of the equipment during installation and use.

  Phantom filling tools: shall include all utensils used in the process of removing air bubbles and replenishing the solution.

A.3. The phantom can be used for measurements

- Geometric distortion
- Spatial Resolution
- Slice thickness and position
- Gap
- T1 and T2 values
- Image bandwidth
- Low contrast detectability
- Image Uniformity
- Signal-to-Noise Ratio (SNR)
- Physical and electronic slice shift
- Reference Points

  Bandwidth: Water-fat shift



2. The phantom is mainly capable of image scanning and has image analysis functions:

B.1. Geometric Accuracy

Geometric accuracy testing evaluates the accuracy with which an image represents the true dimensions of the imaged object. It involves measuring the length and diameter of a phantom, between easily identifiable locations within the phantom, and comparing the results to the known phantom dimensions. A fault indicates that the difference between the measured dimensions and the actual dimensions is far greater than that of a scanner operating normally.

Geometric accuracy is evaluated using the ACR sagittal localizer images and slices 1 and 5 of the ACR axial T1 series. The material of the insert constructed in slice 5 varies depending on the date the phantom was manufactured. For older large ACR phantoms, slice 5 will consist of a grid. Medium-sized phantoms and newer large phantoms will have an acrylic insert with equally spaced holes. The function of both inserts is the same to guide measurements.

B.2. High-Contrast Spatial Resolution

The high-contrast spatial resolution test evaluates the scanner's ability to resolve small objects when the contrast-to-noise ratio (CNR) is sufficiently high.

Failure of this test means that, for a given field of view (FOV) and acquisition matrix, the scanner cannot resolve small details like a properly functioning scanner would. However, since clinical protocols are usually adjusted to optimize high-contrast resolution, if the station resolution of the ACR series fails, apply this test to the station series. The submitted images must pass either one of the ACR series or both of the website series.

B.3. Slice Thickness Accuracy

The slice thickness accuracy test evaluates the precision of slices that meet the specified thickness. The specified slice thickness is compared with the measured slice thickness.

Failure of this test means that the scanner produces slices with a thickness that is fundamentally different from the specified thickness. This problem usually does not occur in isolation, because scanner defects that can cause it may also lead to other image problems. Therefore, the impact of failure is not only that the slices are too thick or too thin, but may also result in poor image contrast and low signal-to-noise ratio.

B.4. Slice Position Accuracy

The slice position accuracy test evaluates the accuracy of specifying slices at specific positions using the localizer image as a position reference.

A failure of this test means that the difference between the actual position of the acquired slice and the specified position is far beyond the normal level of a normally operating scanner.

B.5. Image Intensity Uniformity

The image intensity uniformity test measures the uniformity of image intensity in a large area near the middle of the imaging volume, which is usually close to the center of the head coil.

The head coil typically has fairly uniform spatial sensitivity near the center of the coil. However, the signal distribution varies with the coil design. Phased array coils naturally produce brighter signals at the periphery immediately adjacent to the smaller coil elements, so intensity or uniformity correction needs to be applied to pass this test.

Since the ACR MRAP phantom is filled with a conductive solution, the dielectric effect is significant at field strengths of 3 Tesla and higher. The occurrence of this artifact is because, as b0 increases, the radiofrequency wavelength decreases until they approach the size of the phantom. Standing electron waves converging on the phantom from different directions can create patterns of destructive and constructive interference in different regions of the phantom. This typically manifests as brightening at the center of a high-conductivity phantom. Due to the dielectric effect, it is recommended to use the same intensity inhomogeneity correction method as for clinical images to acquire the phantom image.

A failure in the uniformity test indicates that the scanner/coil combination exhibits significantly greater variations in image intensity than a normally operating system. A lack of image intensity uniformity may indicate the following situations: (1) Intensity inhomogeneity correction is not used; (2) there is a defect in the scanner; (3) a defective head coil; and/or (4) problems present in the radio frequency sub-system.

B.6. Signal Ghosting

The percentage signal ghosting test assesses the degree of ghosting in ACR T1 images. A phantom is an artifact that superimposes a faint copy of the image object (the phantom) onto the image and displaces it from its true position. If there are many low-level ghosts, they may not be recognizable as copies of the object but rather as smearing of the signal emanating from the phase-encoding direction of the true image. Ghosting is a result of signal instability between repetitions of the pulse cycle. In this test, the ghost signal level is measured and reported as a percentage of the signal level in the true (primary) image.

The phantom is most prominent in the background areas of the image, where there should be no signal, but the ghosting also covers the main part of the image, altering the true image intensity. A failure of this test indicates that there are ghosting artifacts at a level significantly higher than that observed in a normally functioning scanner.

B.7. Detectability of Low-Contrast Objects

The Low-Contrast Object Detectability (LCD) test assesses the degree to which low-contrast objects can be identified in an image. For this purpose, the phantom has four sections with low-contrast objects of varying sizes and contrasts.

The ability to detect low-contrast objects is primarily determined by the signal-to-noise ratio and the contrast-to-noise ratio (CNR) obtained in the image, and may be reduced by the presence of artifacts such as ghosting.

CNR performance is highly affected by field strength. Clinical protocols are usually adjusted based on this. Therefore, if the low-contrast object detection of the ACR T1 and T2 series fails, apply this test to the on-site series. Most scanners can pass the ACR series tests, and this is sufficient for the scanners to pass the two-site series.

A failure of this test indicates that the images produced by the scanner show significantly fewer low-contrast objects than most clinically functioning scanners. Typically, a failure indicates a low signal-to-noise ratio. However, in some cases, artifacts such as ghosting may also play a role.

3. Positioning of the Phantom

During positioning, it is necessary to ensure that the phantom remains level in all directions (Figure A.2), and the image positioning method is shown in Figure A.3. The recommended necessary scanning sequences by ACR (Table A.1) include a T1W-SE sagittal sequence (midline positioning image, \(FOV ≥ 240 × 240 ~mm^{2}\), 1 layer, slice thickness: 20mm), a T1W-SE axial sequence \((FOV ≥ 240 × 240 ~mm^{2}\), 11 layers, slice thickness: 5mm, slice spacing: 5mm, \(pixel < 0.9 × 0.9 mm^{2}\)), and a T2W-SE axial sequence (FOV 240x \(240 ~mm^{2}\), 11 layers, slice thickness: 5mm, slice spacing: 5mm, \(pixel < 0.9 × 0.9 ~mm^{2}\)). On this basis, the tester can add other axial test sequences with consistent geometric parameters according to their needs.

Figure A.2 Phantom Positioning

The phantom is marked with "CHIN" and "NOSE" to facilitate orientation discrimination. A bubble level can be used to ensure the phantom is level in all directions. During positioning, align the built-in laser line with the black cross on the upper surface of the phantom.

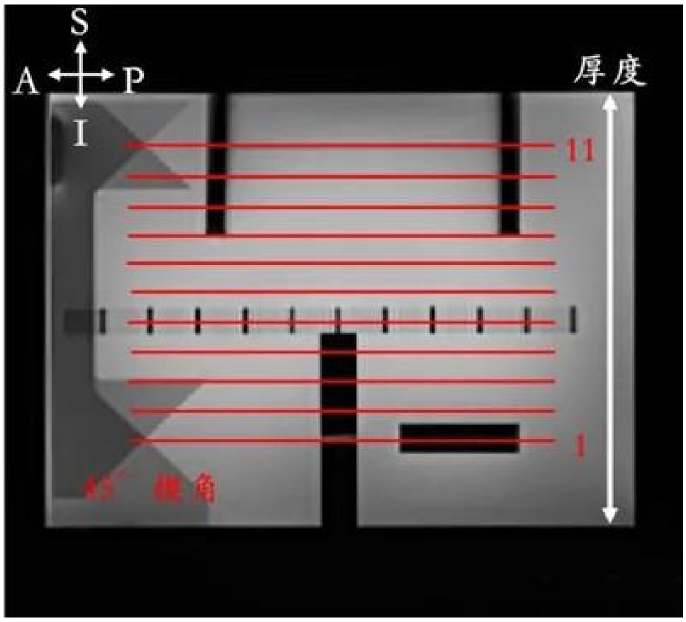


Figure A.3 Defining the axial scan range on the sagittal image of the phantom

The first and last slices are placed exactly at the center of the 45° wedge intersection. The slice position accuracy calculated on the axial images allows for the quantitative evaluation of the consistency between the actually scanned encoded slices and the slice positions defined on the localizer images.