Automated analysis of ACR phantom data as an adjunct to a regular MR quality assurance program

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Introduction

We report the development of a package of Matlab-based functions for automated analysis of phantom images. The functions are used to obtain measurements for a series of tests that assess the image quality of an MR scanner to complement a regular program of MR quality control. The quality control program for accreditation by the American College of Radiology (ACR) requires that phantom images be analyzed weekly. Thus, at each of our sites, images are acquired by MR technologists and measurements from the images are used to assess, for example, resolution and geometric accuracy of individual MR scanners. With the standardized ACR phantom, many other tests to assess quality, such as measures of SNR, image uniformity and ghosting can also be done and this could be useful for quickly identifying quality issues. However, including a comprehensive suite of tests is not practical *as part of the weekly program*, particularly for a site with a large number of MR scanners. An automated analysis package, therefore, may be useful as an adjunct to an established quality assurance program and as a tool for the MR physicist overseeing it.

Methods

Scans: Weekly scans of the ACR phantoms were performed on five 1.5T GE Signa MR scanners by certified MR technologists with specific training on positioning and scanning the ACR phantom. For each scan session, after initial positioning, a single T1-weighted mid-sagittal slice is obtained and eleven 5mm axial slices are prescribed according to the ACR phantom scanning instructions [1]. All images are transferred to a central server and then to a database for automated analysis. Figure 1 shows the first of the eleven T1-weighted (TE/TR = 20/500 ms) axial slices of the ACR phantom.

Phantom tests: Seven basic tests are described in the instructions for scanning with the ACR phantom [1] and our goal has been to automate these tests along with several additional ones. The basic tests include: (1) a geometric accuracy test that involves measuring several lengths in images of the ACR phantom, (2) a high-contrast resolution test to determine whether individual bright dots can be detected, (3) a slice-thickness accuracy test that involves a measurement of bars in the phantom image, (4) a slice position accuracy test, (5) an image intensity uniformity test, (6) a ghost quantification test, and (7) a low-contrast object detection test. Along with automating the basic tests, we have included functions for tests such as one to measure SNR and others to assess the alignment of the phantom in terms of its rotation in axial, coronal and sagittal planes.
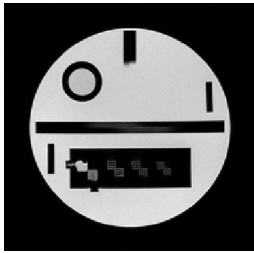

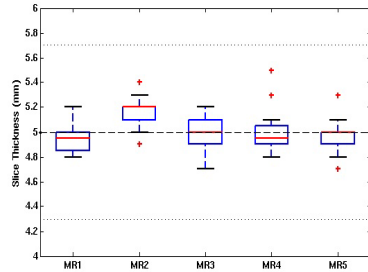**Fig. 1: Slice 1 of 11 axial ACR phantom images.**

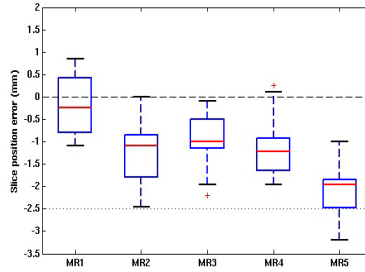**Fig. 2: Automated slice thickness measures for 5 different 1.5T systems.**

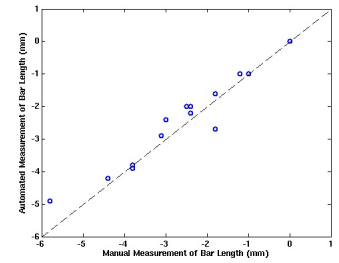**Fig. 3: Slice position errors computed from automated measures.**

Fig. 4: A comparison between automated and manual measures.

Results

Figures 2 and 3 show box-whisker plots of measures obtained by analyzing the phantom images from five MR scanners over a period of four months. The boxes in the plots show the range between the lower and upper quartiles of the distributions for measures and the red line shows the median. The whiskers (black bars) are placed at the extreme upper and lower points of the data that fall within 1.5 times the inter-quartile range. Outliers are plotted with red crosses. Slice thickness measure: Figure 2 shows a plot of the slice thickness estimates obtained by measuring the length of two horizontal bars in the first slice image. The bars are produced by sample in two grooves in the phantom that are precisely positioned so that the combined length of the bars is directly proportional to the slice thickness. According to ACR guidelines, the values should be within 0.7 mm of the true slice thickness, which is 5mm. Black dotted lines in the plot show the range of acceptable values. No measurements for any of the systems fall outside the acceptable range. Slice position accuracy: Figure 3 shows a plot of the slice position errors obtained by measuring the difference between the lengths of two vertical black bars in the first slice image. The bars are produced by wedge-shaped pieces of Plexiglas that, if the slice is positioned correctly, create voids of equal length in the image. The difference in lengths of the bars is directly proportional to the error in positioning of the slice. For four of the MR systems, all measures are well within ACR specifications (<2.5mm). However, some measurements on system MR5 are outside the acceptable range. In this case it was determined that the table positioning mechanism was faulty and corrective action was taken. Validation: The measures obtained by automatic analysis were validated by comparing them with those obtained by manual measurement on images using analysis tools in the OsiriX dicom viewer. As an example, Fig.4 shows a comparison of the manual and automated measurements for the bar length used to determine slice positioning error from the images on one of the five scanners. Correlation between the two measures in this case is better than 0.96. For certain measurements, such as those used for determining slice thickness, the agreement is not as close. This would be as expected because the manual measurement method is more subjective and is therefore prone to operator-based variation.

Discussion

The analysis reported in this work was limited to images using a T1-weighted spin-echo sequence to acquire data using the ACR phantom placed in the standard quadrature head coil. The software package can, however, be extended to analysis of images using other coils with appropriate phantoms and such a regular (e.g. monthly) quality check could be useful to identify other potential system problems. Currently all images are transferred to a central server where they are analyzed using the Matlab functions. Alternatively, the software package could be compiled and installed to run directly on the MR scanners with results logged or transmitted automatically for review by MR physicists.

References:

[1] Site scanning instructions for use of the ACR MRI accreditation program. The American College of Radiology, Reston, VA; 2005. www.acr.org.