Standardization and Automatization of Quality Assurance in Structural and Dynamic MRI.

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Introduction and Purpose:

Standardization and quality assurance (QA) in magnetic resonance imaging (MRI) are essential both for clinic and research. Yet, the frequency and methods of QA vary significantly. Several MRI vendors perform yearly and quarterly QA utilizing their own software into which the end user usually gets no insight. In 2005 the Norwegian Radiation Protection Authority made recommendations that demand all MRI clinics and centers to have at their disposal a physicist to carry out a yearly vendor independent QA routine. However, the methods used in these routines are often varying and manually intensive. One consequence being that results vary to such a degree that cross-vendor and -system comparison becomes difficult. This is especially a challenge in larger hospitals with different MRI vendors and systems. In addition, several of the methods currently in use are prone to operator errors. The MRI Quality Assurance Package (MRI--QAP) is an open source QA software designed to address these issues, expand on the existing QA procedures, remove subjective assessments and ensure consistency of results. Currently, the software consists of various separated independent modules that perform different tasks, such as geometric distortion, signal to noise ratio, uniformity and dynamic stability analysis.

Methods and materials:

A large Perspex phantom (Ø40 cm) that is used in the QA routine of the local physicists with 45 measurement points was used for the evaluation of geometric distortion in spin echo based images. A circular Hough algorithm (1) was used to find the positions of all the measurement points. In order to evaluate matching results between the geometric distortion software and current manual methods, artificial MRI images with known distortion percentages were constructed. The difference between software calculated and actual values in 100 images were assessed with statistics for individually measured points. A similar test was done comparing human reader measurements with automatic calculated values. Uniformity and SNR image acquisitions were done in the homogenous part of the same phantom, followed by an analysis based on a simple pixel-by-pixel estimation of signal values and the Hough algorithm for the positioning of phantom center. Data from several years of previous QA sessions were analyzed and compared with results from a similar in-house developed program (programmed in IDL). Methods for measuring geometric distortion, SNR and uniformity followed recommendations given by NEMA (2). The new QA procedures calculating temporal SNR (tSNR), percent fluctuation, signal drift and the Weisskoff plot are built on modified methods from relevant articles (3, 4). The code has been written in Matlab (R2012b) with the Image Processing Toolbox.

Results:

The MRI-QAP program package is confirmed to be working well within expectations. Several tests have been done to validate its reliability and efficiency. Measured values of geometric distortion in the artificial images were shown by t-tests to be no different than the known values ($p < 0.05$). A result being that the automated program performed geometric distortion analysis as well as, and in some cases better, than human readers and in much less time. Figure 1a shows an image output validating measurement points in the geometric distortion module. The red circles in the center are indicating objects registered by the Hough transform as points to be used for further calculations. Figure 1b shows a strong correspondence between the estimation of 20 different points in our phantom analysed with MRI-QAP and manually by 5 physicists.

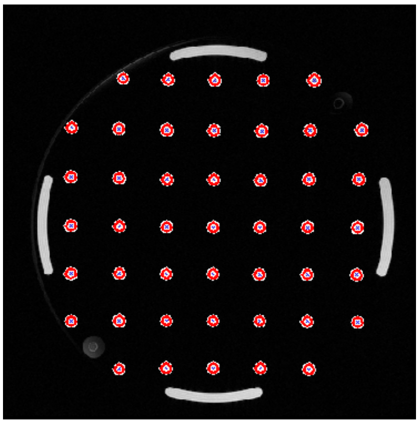

Figure 1a: Hough transform detection method for geometric distortions in a phantom image. The red circles indicate localization of the various measurement points in the phantom.

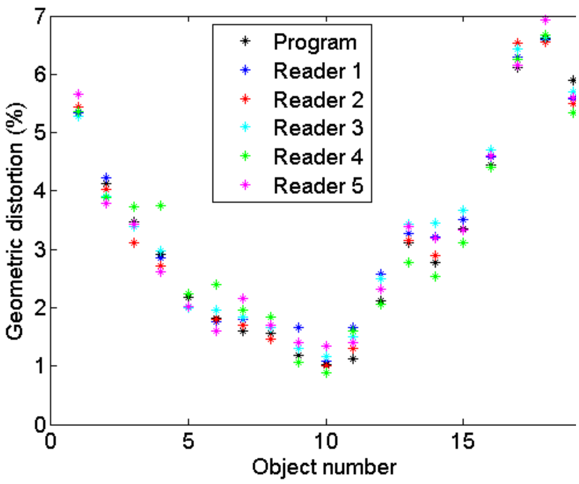

Figure 1b: Geometric distortions in percentage calculated for 20 points in our phantom, both with MRI-QAP and 5 different physicists.

The uniformity analysis performed with almost identical outcome as the previously used IDL-based program. SNR values have experienced some discrepancies from earlier measurements, which will be studied more closely. In the dynamic QA analysis drift percentage and signal fluctuation are determined based on a selected ROI size and written to file. In addition, tSNR and Weisskoff plot analyses are implemented for investigation of MRI system instabilities. The program package is designed to be highly modular in an effort to give local research groups insight into the code, and to make it easier to modify existing code and add new modules. The MRI-QAP program is MRI vendor and system independent, making it valuable for groups that wish to study long-term system stability, and for doing multi-vendor and -system comparisons.

1. Size invariant circle detection. T.J. Atherton, D.J. Kerbyson
2. NEMA Standards Publication, MS 2-2003, MS 1-2008, MS 3-2008
3. Report on a Multicenter fMRI Quality Assurance Protocol. Lee Friedman, PhD and Gary H. Glover, PhD
4. Simple Measurement of Scanner Stability for Functional NMR Imaging of Activation in the Brain. Robert M. Weisskoff