Automated Quality Control for ACR Compliance

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JULY 12–16 2020 VIRTUAL
JOINT AAPM | COMP MEETING
EASTERN TIME [GMT-4]

INTRODUCTION

The American College of Radiology (ACR) requires a Qualified Physicist to review a weekly Quality Control (QC) program, which can be challenging at multi-site institutions. A small number of attempts have been made to design custom MRI image processing software (1,2). This work set out to automate the requirement to increase compliance and consistency. Although focused on ACR MRI weekly QC, it could be modified for any DICOM modality.

The most important step is to setup a server within the hospital firewall that can also act as a PACS node to the main database. The Linux based operating system uses HTML, Perl, bash, DCM4CHE, Orthanc, Python, and C/MATLAB languages. The knowledge needed of this broad range is shallow, and it is possible to substitute many other software or condense the list above, based on creator preference.

An initial upfront investment in time can greatly reduce the effort needed to maintain a multi-center, multi-scanner QC program.

AIM

Describe a custom built system for storing, retrieving and analysing weekly QC DICOMs for ACR compliance.

Evaluate a homemade MATLAB routine for analysing Large Phantom data and compare to Annual Physicist measurements for distance, high contrast resolution (HR), low contrast resolution (LCD), ghosting ratio (GR) and uniformity.

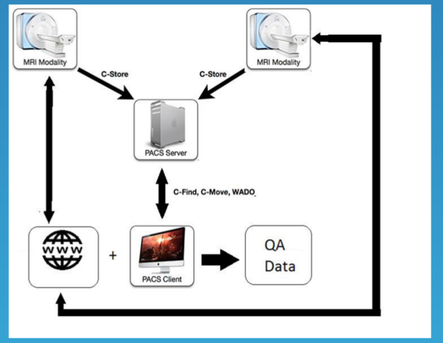
METHOD

Storage and retrieval of DICOMs, notification system:

1. Setup webserver using Ubuntu 18.04 LTS, hosting a webform with ACR instructions and Visual Checklist data entry
2. When MRI Tech completes scan use a non-numerical MRN/Name (“MRACRQA”), send to PACS for storage and later retrieval. Webform data entry is stored in an XML file on the server via a Perl script.
3. The main bash script checks daily for current XML submissions and uses the DCM4CHE findscu command to pull DICOM info of any recent “MRACRQA.” For a given scanner, if the DICOM date matches the XML submission, the T1 Sagittal and Axial images are pulled to the local PACS server from the Main hospital database.
4. Although not required, the incoming DICOMs are sent to separate server running MATLAB, which does the post processing of new DICOMs that day.
5. Each day the server checks whether an XML and DICOM were both sent and notifies the Tech manager otherwise.
6. If the date of the processed automated XML matches the date on the XML submission, a Python script (using openpyxml) extracts the data from the 2 XML files and writes them to a master Excel spreadsheet. Each of the 14 scanners has a dedicated sheet.
7. Once a week, the Excel spreadsheet and a summary of the submissions are sent to the Operations and Physics teams.

MATLAB Analysis Routine:
Phantom Scanning: The DICOMs from 18 Annual Physicist exams of 13 different scanners were used, and the physicist measurements were the reference.

1. The sagittal length algorithm uses the Sobel edge function, then finds the pixel distance between the top and bottom edges.
2. For the axial distances, the mean water value was found for the first slice and the image binarized. The horizontal and vertical lengths were derived.
3. For the high contrast resolution, the HR insert is windowed, then the first hole location is found. The pattern is then searched for 4 complete holes in a row or column.
4. For GR, the center of slice 7 is found, then a 190 mm2 roi is averaged, then 4 rectangular rois are averaged away from the phantom. The uniformity section uses the same large ROI and finds the largest and smallest 100 values for calculation. This is different from the ACR method.
5. For the LCD only the last slice is used, the Sobel edge function finds the circles, then they are counted radially. Anything less than 10 fails.



RESULTS

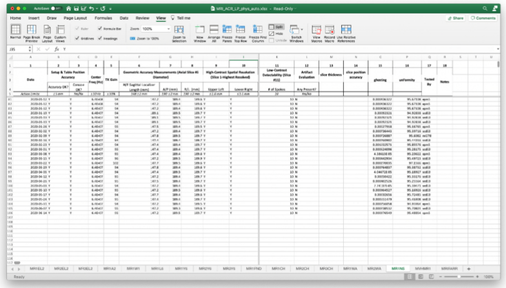


Fig 1. A sample Excel document automatically created and sent with the QC program.

Fig 2. Distance measurement error for automated analysis of Sagittal (z), and Axial (x, y) lengths

Completed	Missed	Percentage
1051	53	95

Table 1. Sum of the 15 scanners weekly QC submissions and missed tests, including scheduled downtime over 1.5 years.

	Completed	Missed	Percentage
HR	34	2	94
LCD	18	0	100

Table 2. Performance of algorithm on high resolution and low contract detectability using Physicist exam as reference

	Correlation Coefficient
GR	73%
Uniformity	76%

Table 3. Correlation between algorithm and physicist on ghosting ratio and uniformity measurements

CONCLUSIONS

The automated analysis works on a weekly basis for easier tracking and more consistent QC measurements. The automated QC system increases compliance (>95%) and provides a backup of ACR data. The average absolute distance error measurement was about 1 mm, or one pixel size, the HR section was identified 94% of the time and the LCD section was identified 100%. There was good correlation between the algorithm and physicist measurement for ghosting ratio and uniformity. There is a clear bias towards overestimating the Sagittal length but underestimating the Axial ones (Fig 2). The former uses a Sobel (gradient) edge detection, while the latter uses the mean water to threshold a binary image so this might be expected.

Having historical QC readily available on the PACS system makes it easier to forward the results to outside collaborators, in pharma for example, as part of their verification process. Because the MATLAB routine is a separate function, other modalities can be used, or alternative QC phantoms for MRI.

Ghosting Ratio or Uniformity implemented into the automated analysis reveals problems on a weekly basis instead of an annual one. For example, a high GR level prompted an early service call to the manufacturer.

It’s possible the precision is more important then the accuracy for the MATLAB routine. However the algorithm determines the measurements, if they are consistent than relative information can be gleaned. The week to week checking will tell if something has happened to the MRI system that needs attention. An under appreciated part of the automated program is the recording of Center Frequency and Transmit Gain from the DICOM header. This was the largest source of data entry error, which has now been eliminated.

ACKNOWLEDGEMENTS

Thanks to John Kirsch, PhD for the discussions on the algorithm

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