

How to routinely evaluate geometric accuracy for radiotherapy planning use?

Using MR images in Radiation Therapy places high demands on the geometric accuracy of the acquired MR information. A quality assurance program should be established that includes frequent and repeatable analysis of the MR system's geometric accuracy, as several factors can influence the scanner's performance over time.

The Ingenia MR-RT comprehensive MR simulation solution includes an intuitive, easy-to-use geometric QA analysis program for routine evaluation of the geometric accuracy of the MRI system [1]. It consists of a dedicated QA phantom and analysis software. Using automated workflow steps, you can perform volumetric, multi-slice 2D evaluations covering a 3D volume. Furthermore, you get a fast, automated Pass/Fail result on the scanner's geometric accuracy.

A dedicated phantom

The Geometric Quality Assurance Phantom is a flat, transparent plate filled with a rigid grid of MR visible spherical markers 9 mm in diameter. The grid spacing between markers is 25 mm. The phantom covers an analysis volume of 50 x 45* x 40 cm³ (RL x AP x FH).

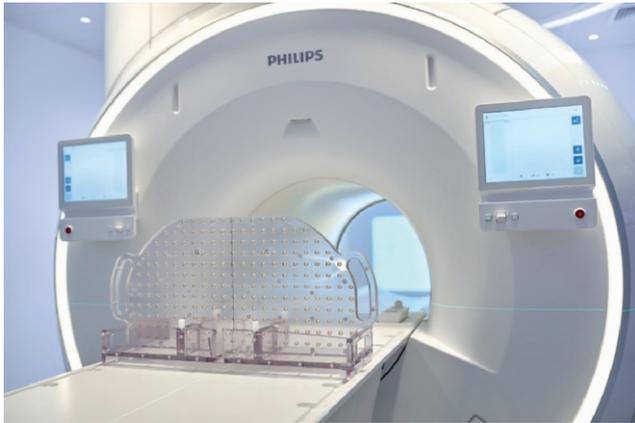
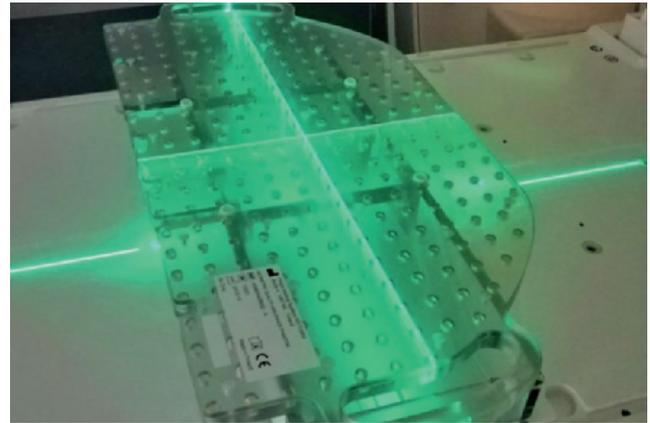


Figure 1: Transversal and coronal positioning of the phantom

The Geometric Quality Assurance Phantom Rack enables positioning of the phantom in three orientations (transverse, coronal, and sagittal).



Automated scanning

The QA procedure is designed to be easy to execute. After placement of the phantom on the MR-RT CouchTop, a geometric batch file can be selected on the MR console, and the QA procedure runs automatically, so operator time is kept to a minimum.

The total scan time for the transversal analysis is approximately 15 minutes. A short phantom position check scan is made before the actual QA scan to make sure there are no significant phantom positioning errors that could make the QA fail. The Geometric QA Phantom is scanned in transverse orientation at seven different locations along the axis of the magnet bore (-200 mm, -130 mm, -60 mm,

± 0 mm, +60 mm, +130 mm and +200 mm). This provides 25 images per each location and maximum intensity projections (MIPs) calculated along all three axis for 3D evaluation. The table moves automatically and no user interaction is necessary. The scan is run with a predefined sequence closely resembling the clinical T1 weighted 3D FFE sequence, which is part of many of the dedicated Philips MR-RT ExamCards.

Distortion in the head-foot direction can be evaluated with the phantom in coronal position. The scanning protocol of coronal analysis takes approximately 5 minutes and consists of one scan at the isocenter.

*Effective FOV above the table of 30 cm

Geometric QA analysis with the automatic algorithm

After the QA scanning is finished, the Geometric QA Analysis tool automatically analyzes the acquired images. For the transversal scan, the software applies automatic correction of small phantom offsets and rotations for a more accurate analysis. The analysis algorithm then automatically detects the center of mass location of each of the markers and compares them to their known ideal locations. The distortion for each marker is defined as the difference in-plane between the detected and physical marker position.

The analysis shows the measured distortion [mm] in predefined volumes around the isocenter for both transversal and coronal scans (see figure 2). The diameter of each volume [mm] is denoted in the Diameter Spherical Volume (DSV) column. The values for DSV 400 mm and 500 mm are calculated from the phantom markers located inside these volumes, as the phantom does not cover the entire spherical volume.

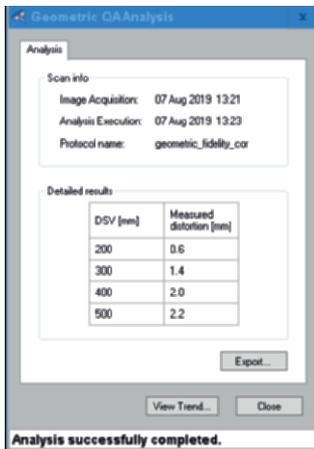


Figure 2: The result window of the Geometric QA Analysis tool showing measured distortion with phantom in coronal position.

Pass/Fail analysis

In the transversal analysis, the automatic Geometric QA Analysis tool compares the measured distortion values to predefined threshold* values in predefined volumes around the isocenter. If the measured distortions are below the thresholds in all volumes, the result window of the Geometric QA Analysis tool shows a 'Pass' result. If the measured distortion exceeds the threshold in one or more of the predefined volumes, the result window shows a 'Fail' result (See Figure 3). The process is simple and automated, delivering a fast, clear decision with no inter-observer variability.

If a failure is indicated, the cause should be explored before continued clinical use of the system. It is the responsibility of the site to determine whether or not continued operation is reasonable. Should the site not achieve a resolution to the problem, Philips service can be contacted to assist.

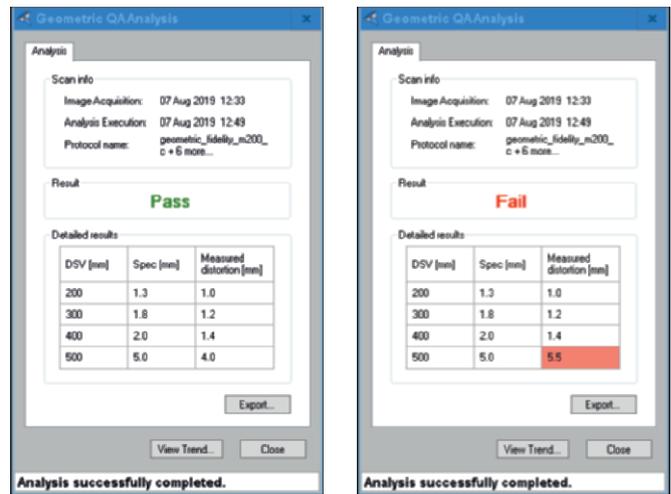


Figure 3: The result window of the Geometric QA Analysis tool. Left: The measured distortions are below the predefined thresholds. The result window shows a 'Pass' result. Right: The measured distortion exceeds the predefined threshold. The result window shows a 'Fail' result and highlights the distortion that exceeds the predefined threshold.

*Thresholds are predefined and based on typical data derived from Ingenia MR installations in more than 10 hospitals, for both 1.5T and 3.0T.

Trend reporting of distortion QA data

It is also possible to view trends directly on the MR console to identify possible changes in the system performance as a function of time, see figure 4. A general rule is that the distortion values should remain constant over repeated runs of the Geometric QA. A persistent change may indicate

a change in the MR or MR-RT system's mechanical, electrical, or magnetic performance, a change in the imaging parameters, or damage to the Geometric QA Phantom. The trend data remains available on the console even if the MR images are removed from the patient database.

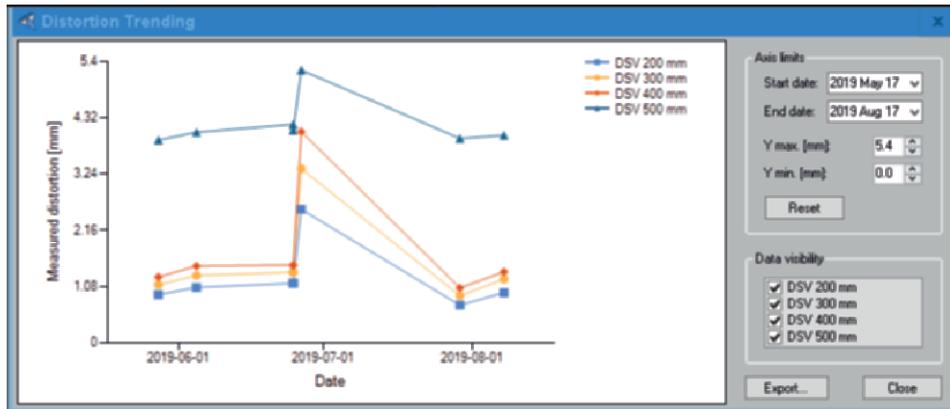


Figure 4: Trend plot of the historical analysis results for the predefined spherical volumes

Export of QA results

Data can be easily exported as a text file to other software programs for advanced evaluation. The text files includes the detected x, y, and z coordinates for all markers in the phantom, as well as:

- A figure overlaying the scanned image, expected marker locations and observed marker locations (see figure 5)
- A figure showing the distortions as a color map (see figure 6)

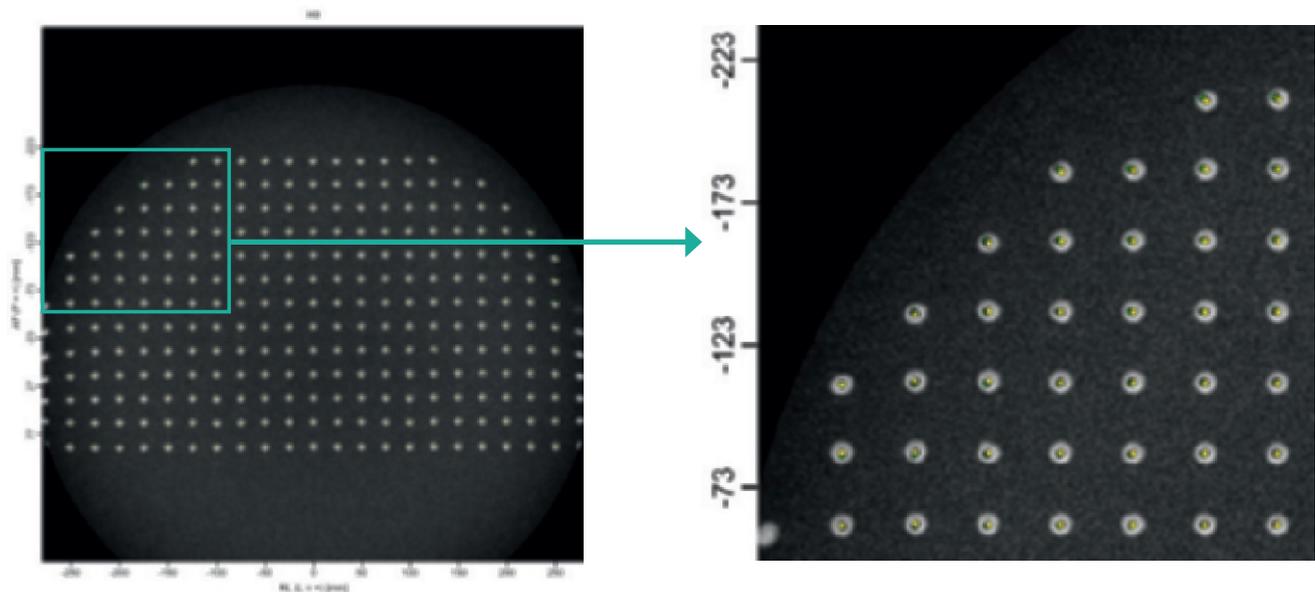


Figure 5: An example figure overlaying the scanned image, expected marker locations and observed marker locations. Left: Full view. Right: Zoomed in view

- Observed position
- Reference position

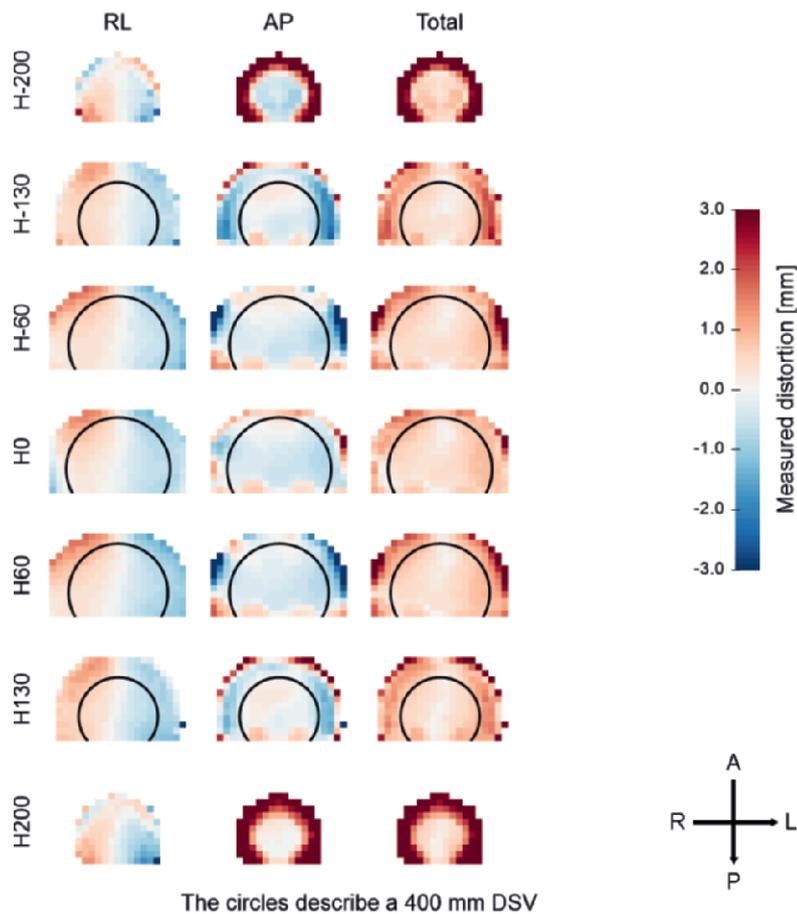


Figure 6: An example color map of the measured distortions.

Backwards analysis

All phantom images acquired are stored in the patient database. It is possible to analyze previously acquired geometric QA images, for example if the Pass/Fail analysis was closed without evaluation or if a double check by other staff members is needed.

Frequency of QA analysis

You should perform the Geometric QA procedure periodically to check the homogeneous volume of the MR system and the degree of systemic geometric distortion over the field of view. It is recommended that the Geometric QA Analysis be performed at least weekly as indicated in the Instructions for use.

Depending on your institute's protocols, the geometric QA analysis can be performed by RTTs or by medical physicists. It is advised that advanced QA or interpretation of trending data is performed by a physicist.

Reference

1. Quality assurance measurements of geometric accuracy for magnetic resonance imaging-based radiotherapy treatment planning. Iiro Ranta, Reko Kemppainen, Jani Keyriläinen, Sami Suilamo, Samuli Heikkinen, Mika Kapanen, Jani Saunavaara, Phys. Med. 62 (2019) 47-52.



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