MRI Acceptance Protocol for the Multicenter GO Glioblastoma Project

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Introduction

Quality control (QC) protocols are now routinely used on clinical Magnetic Resonance Imaging (MRI) devices. Most of the time, these QC procedures are manufacturer-specific, and then not useable for multicenter projects involving multiple MRI systems from different vendors on different sites. The aim of the work package 1 of the Grand Ouest Glioblastoma Project (GOGP) [1], a multicenter bio-clinical study, was to find new imaging parameters with non-invasive method to highlight the heterogeneity and margin of the multiform glioblastoma (Fig. 1) and to enhance the grading prognostic. These new imaging biomarkers have to be correlated to biological biomarkers extracted from biopsies by Neuronavigation. In this multicenter project, that included an identical MRI protocol realized on different MRI devices, the key-point was the initial acceptance of imaging devices and sequences. For this purpose and to allow quantitative patients data comparison [2], we have proposed a specific common protocol for quality assessment.

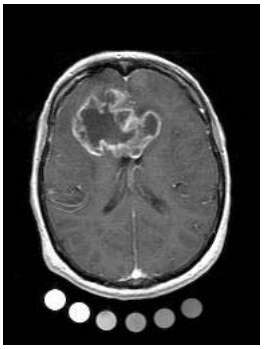

Fig. 1 Postcontrast brain MR image with a multiform glioblastoma from T1 dynamic series.

Materials and methods

7 different MRI devices used for clinical routine from three manufacturers were involved: Siemens Medical Solutions (Erlangen, Germany), Philips Medical Systems (Best, Netherlands) and General Electric (Milwaukee, WI, USA). All magnets were 1.5T and located on six different centers. To allow inclusion of MRI devices and patients, an acceptance QC was performed on each site. A second QC for verification has been executed on some sites. From the GOGP protocol, we selected the 3 sequences needed for tumor heterogeneity quantification:

- T1w and T2w spin echo sequences that were also used for texture analysis purposes.
- T1w gradient echo with a 90° flip angle (DYN90) that was used for Dynamic Contrast Enhancement MRI (DCE-MRI).
- A third set of T1w spin echo sequences with multiple repetition times (T1SE-Multi TR) to validate T1 measurements needed for DCE-MRI.

All sequences were run in transversal plane. Imaging parameters are listed in Table 1.

Table 1. Imaging acquisition parameters. For all these sequences the slice thickness was 5mm.

Sequences	TR (ms)	TE (ms)	FOV (mm)	Matrix	Averages	Slices number	Gap (mm)	Echoes train
DYN90	150	5.6	180x240	192x256	1	13	0.5	-
T2W	4120	130	240x240	256x256	2	24	1	18
T1W	440	10	240x240	256x256	2	24	1	-
T1SE-Multi TR	50 to 6000	10	240x240	256x256	1	1	-	-

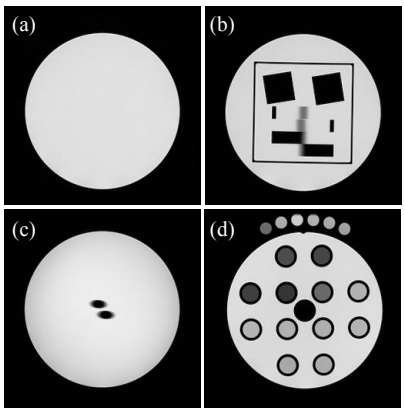

Fig 2. Transversal MRI slice images of the Test Objects (a) TO1, (b) TO2, (c) TO3, (d) TO4 and a set of six tubes

The SpinSafety® phantom set included four SpinSafety Test-Objects (TO) (Fig. 2) filled with a dilute solution of copper sulfate giving a T1 of 350 ms at 1.5T. The GOGP imaging protocol included for each patient dynamic acquisitions and T1 measurements using 6 reference tubes containing solution of known T1 covering those encountered in the brain. During the GOGP imaging protocol, these tubes were placed around each patient head (Fig. 1) and used as an external reference for T1 correction. During the QC protocol, these tubes were imaged along with the TO4 (Fig. 2-b). The measurement protocol was elaborated in accordance with the Eurospin Project [3]. The 10 parameters under examination were signal variations along frequency encoding direction, signal variations along phase encoding direction, Signal to Noise Ratio (SNR), slice thickness, slice position, spatial resolution, mean diameter, circle diameter distortion, square sides and diagonals distortions and T1 accuracy.
Parameters measured with TO1 and TO4 were considered to control the quality of GOGP sequences that were used for T1 measurements and quantification, whereas TO2 and TO3 were considered to control the quality of spatial localization and geometry distortions of sequences used for neuronavigation and MRI guided biopsies [4]. Student t-test for the conformity study and Analysis of Variance (ANOVA) were used to obtain statistical data. Following the ISO 5725 norm, reproducibility and repeatability were studied.

Results-Discussion

The mean SNR ranged from 203 for the T2w to 154 for the DYN90. This SNR is a key parameter for the subsequent T1 measurement procedure needed to compute the DCE-MRI parameters. A Monte Carlo simulation was then developed to propagate the noise measured on images to the errors on T1 computed values. This simulation showed that the mean SNR of the DYN90 sequence corresponds to a maximum error on T1 of 0.02s with a T1 of 1s and 0.08s with a T1 of 2s. This represents a relative error on the computed T1 of less than 4%, which is acceptable [2] for the subsequent dynamic quantification procedure.
The signal variations on phase and readout directions were less than 5%. The mean spatial resolutions were 0.93, 0.96, and 1.06 for the T2w, T1w and DYN90, respectively. A Student t-test has also showed that spatial resolution measurements were close to the theoretical value of 0.94 mm. Slice thickness was analyzed with an ANOVA test with the sequences as a between-subjects factor (i.e., T2w, T1w and DYN90). There was a reliable main effect of the sequences, with means of 5.2 mm, 5.0 mm and 5.8 mm for the T2w, T1w and DYN90, respectively, $F(2, 30) = 12.9$, $p<0.0001$. A Student test has also showed that slice thickness measurements are close to the theoretical value of 5 mm except for DYN90 sequence with a $p\leq0.001$. But this significantly increased slice thickness of the DYN90 compensates for the inherently lower SNR of this short imaging sequence. The other parameters were constant over the sequences and were close to the theoretical values. In summary, geometrical results for all the parameters and all the systems presented accuracy in the order of 1 to 2 millimeters, which allowed an acceptable positioning of the biopsy region by neuronavigation imaging [5].
Repeatability variation coefficient for tubes of the T04 ranged from 8.9% to 11.4% and reproducibility variation coefficient ranged from 7.3% to 13.2%. As an example, the general mean for an external reference tube is 416 ms and the reproducibility standard deviation was 24 ms. This good precision was mandatory in T1 measurement procedure in order to compare DCE-MRI parameters obtained in the 6 centers.

Conclusion

As a result, these different QCs allowed to include patients from the different sites and to extract tumor quantification parameters that are comparable independently from the origin of the images and to ensure that these extracted MR parameters and image-guided biopsy samples refer to the same spatial coordinates. Such simple quality assessment testing should be mandatory in any multicenter clinical research projects involving quantitative MRI and correlation between extracted data of biopsies.

Reference

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