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Original paper

A straightforward multiparametric quality control protocol for proton magnetic resonance spectroscopy: Validation and comparison of various 1.5 T and 3 T clinical scanner systems

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ABSTRACT

Purpose: The aim of this study was to propose and validate across various clinical scanner systems a straightforward multiparametric quality assurance procedure for proton magnetic resonance spectroscopy (MRS).
Methods: Eighteen clinical 1.5 T and 3 T scanner systems for MRS, from 16 centres and 3 different manufacturers, were enrolled in the study. A standard spherical water phantom was employed by all centres. The acquisition protocol included 3 sets of single (isotropic) voxel (size 20 mm) PRESS acquisitions with unsuppressed water signal and acquisition voxel position at isocenter as well as off-center, repeated 4/5 times

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within approximately 2 months. Water peak linewidth (LW) and area under the water peak (AP) were estimated.
Results: LW values [mean (standard deviation)] were 1.4 (1.0) Hz and 0.8 (0.3) Hz for 3 T and 1.5 T scanners, respectively. The mean (standard deviation) (across all scanners) coefficient of variation of LW and AP for different spatial positions of acquisition voxel were 43% (20%) and 11% (11%), respectively. The mean (standard deviation) phantom T_2 values were 1145 (50) ms and 1010 (95) ms for 1.5 T and 3 T scanners, respectively. The mean (standard deviation) (across all scanners) coefficients of variation for repeated measurements of LW, AP and T_2 were 25% (20%), 10% (14%) and 5% (2%), respectively.
Conclusions: We proposed a straightforward multiparametric and not time consuming quality control protocol for MRS, which can be included in routine and periodic quality assurance procedures. The protocol has been validated and proven to be feasible in a multicentre comparison study of a fairly large number of clinical 1.5 T and 3 T scanner systems.

1. Introduction

In vivo proton magnetic resonance spectroscopy (MRS) provides unique biochemical information which can complement magnetic resonance imaging (MRI) examinations. Accordingly, MRS is widely employed in several brain as well as body (e.g. breast, prostate, liver) clinical applications [1–4]. In particular, in the field of oncology, the inclusion of quantitative MRS [5] in multiparametric MRI of tissue has the potential to improve the differential diagnosis between malignant and benign lesions [6].

Quality Assurance (QA) is recommended in conventional MRI and a number of protocols – such as that proposed by the American Association of Physicists in Medicine (AAPM) [7] or the American College of Radiology (ACR) [8], as well as that based on Eurospin test objects [9] – have been proposed and used. However, these protocols are not sufficient to guarantee the reliability of MRS, as well as of non-conventional techniques of diffusion-weighted imaging (DWI) [10–12] and functional MRI (fMRI) [13–15], and the need of specific QA protocols in advanced and quantitative techniques is still established and recognized [7,8].

A preliminary European research project aimed to define specific procedures for MRS quality assurance, developing test objects and methodologies [16–19]. These procedures have been validated in a multicenter trial involving 10 sites [19]. Some studies have proposed QA methods for MRS based on home-built dedicated phantoms [20–23], which however hamper the wide use of these methods. The report of the AAPM Task Group #9 [24] dealt with the topic of clinical MRS, giving a number of general recommendations about QA. Also, the AAPM report no. 100 on acceptance testing and quality assurance procedures for MRI facilities [7] has summarized some MRS acceptance tests – which include the assessment of volume of interest (VOI) localization, signal-to-noise ratio (SNR), full width at half maximum (FWHM) of metabolite peaks in the spectrum and amplitude fluctuations – indicating to acquire short echo time sequences with and without eddy currents correction algorithm. Based mainly on theoretical concepts, the AAPM report no. 100 [7] has suggested a VOI localization accuracy within ± 1 mm, a global water peak FWHM < 7 Hz and < 14 Hz for an MR scanner system with a second order shim set and with only linear shim, respectively. Also, the AAPM report no. 100 [7] has proposed a test for scanner hardware stability, which consists in visually inspect the remnant water peak signal from subsequent water-suppressed water signal acquisitions – the recommended amplitude fluctuations are less than 10%. One can analyze also the unsuppressed water signal by turning off the water suppression radiofrequency pulses. In this case, shot-to-shot signal amplitude variation should be approximately less than 1% and the peak position should not change by more than 1 Hz. Nonetheless, so far only few recommendations have been given and some of them cannot be performed easily by users of scanner systems for clinical MRS. Furthermore, a consensus about acceptable tolerance values of measured quality control indices is lacking. For these reasons, we believe that a specific QA protocol for MRS, which can be applied routinely to most clinical scanners, can be of practical interest. In this regard, multicenter comparison studies can be useful to validate QA protocols as well as to obtain a range of variation across scanners of quality indices, which can represent an indicative and empirical reference for a centre that goes ahead to apply a quality assurance protocol for MRS.

Toward a standardized QA in routine as well as in research studies, a widely accepted and easily applicable quality control protocol for MRS – which can be used for scanner systems with different characteristics/performances – is advisable. The aim of this preliminary study was hence to propose a straightforward MRS quality assurance procedure and validate it on a fairly large number of different scanner systems by 3 different manufacturers. In particular, 16 centres (18 scanner systems) were enrolled in the study among the members of the working group "Quantification and Intercomparison in MR" of the Italian Association of Medical Physics (AIFM).

2. Materials and methods

2.1. Scanner systems and phantom

Eighteen clinical 1.5 T (12) and 3 T (6) scanner systems for MRS, from 16 centres and different manufacturers, were enrolled in the study (Table 1). For each scanner system, standard maintenance and quality assurance procedures were routinely performed.

A standard spherical (diameter 15 cm) doped water phantom (2 mM $NiCl_2 \cdot 6H_2O$ + 0.5 g/l NaN_3) was employed by all centres enrolled in the study.

2.2. Acquisition protocol

All acquisitions were performed by using the head coil (Table 1) at fixed signal gain. The phantom was placed in the magnet room at least 6 h before acquisitions to reach thermal equilibrium. Moreover, the phantom was positioned in the centre of the head coil at least 5 min before starting the acquisitions.

The acquisition protocol included 3 sets of single voxel PRESS sequences (a–c) without water signal suppression. In particular, for each

Table 1
Scanner systems enrolled in the study.

Number of scanners	Manufacturer	Model	Magnetic field strength (T)	Number of head coil channels
1	GE	Horizon LX	1.5	8
1	GE	Signa HDX	1.5	8
1	GE	Signa HDX	3	8
4	Philips	Achieva	3	8
1	Philips	Ingenia Omega	1.5	15
1	Philips	Achieva	1.5	16
5	Philips	Achieva	1.5	8
1	Siemens	Verio	3	12
2	Siemens	AERA	1.5	8
1	Siemens	Avanto	1.5	4