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The Impact of MRS Phantom Container on the Quality of Spectrum Provided by 3T MRI

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This study intended to evaluate the effect of the material of phantom-container on the MRS signal in 3T MRI. Three phantom-container consisting of clear laboratory-glass, PET-bottle, and falcon-tube was used. The metabolites contained 6 mM Cr and 3 mM Cho. FWHM and SNR of Cho and both peaks of Cr were calculated. FWHM of all the peaks of glass-phantom was 50.08 and 19.48 % fewer than those provided by PET and falcon-tube; also, the SNR of the all the peaks of the PET and falcon-tube were by average 77.99 and 91.18 % fewer than the peaks provided by glass-phantom. The laboratory-glass is a good material for building MRS phantoms since it does not affect the baseline-noise, FWHM, and SNR of the spectra. It was also revealed that the size of the phantom and the distance between the spectroscopy volume and phantom walls were important and can affect the baseline-noise.

Keywords : magnetic resonance spectroscopy, magnetism of impurities, phantom, signal to noise

1. Introduction

Magnetic resonance spectroscopy (MRS) is a helpful imaging modality in detecting the metabolic changes in the tissues [1]. The application of this modality in the research area is very popular. There are many studies on the phantoms that were filled by the metabolites simulating a disease or a clinical situation [2-10]. In some studies, the researchers build MRS phantoms that are suitable for their study. However, building a MRS phantom needs some knowledge about choosing the material for the phantom container.

Some factors are important for building the MRS phantom such as chemical and thermal stability, lack of significant chemical shift, having suitable T1, T2, and proton density (i.e. T1, T2, and PD in the range of biological material, for instance having suitable TR which doesn't need a long scan time or having proper T2 which is not less than the T2 that scanner needs for data acquisition). It is also important to avoid the application of colored plastic or the material that creates high magnetic sensitivity in comparison to the material that fills the phantom (e.g. the metabolites) [11]. Inside the phantom should be filled by the metabolites such as choline (Cho), creatine (Cr), N-acetyl aspartic acid (NAA), etc. which are detectable by the imaging system.

Today most of the commercial MRS phantoms such as the American college of radiology (ACR) and Eurospin phantom are made by acrylic [12]. Some man-made phantoms were built using glass, polyethylene, or acrylic [13-15].

A previous study assessed the effect of the phantoms with the containers built by different materials using a 1.5 T MRI scanner. Phantom material can affect the MRS signal because of the magnetism of impurities that can affect the magnetic field or T1 and T2 characteristics of the material. They concluded that the material of the phantom container could dramatically affect the baseline noise and signal to noise ratio (SNR) of the signal provided by 1.5 T MRI scanner. In that study, it was explained that the effect of phantom impurities on the MRS signal provided by 1.5 T MRI scanner is more significant than 3 T MRI scanner because of its fewer SNR [16].

This study aimed to evaluate the effect of the material

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of phantom container on the MRS signal in 3T MRI scanner to show how the phantom material can affect the MRS signal even in 3T MRI scanner, the SNR of which is almost twice the 1.5 T MRI scanner.

2. Material and Method

2.1. Phantom construction

Three phantoms were built in this study. The concentration of metabolites was provided based on the concentration of brain metabolites. The metabolites contained 10 mM Cr and 6 mM Cho solved in distilled water [17]. The ratio of Cho/Cr was the same in all phantoms. Three phantom containers consisted of a 250 cc clear laboratory glass, a 500 cc bottle of mineral water made of poly-ethylene terephthalate (PET), and a poly-ethylene Falcon tube was used. All of them were filled by the mentioned metabolite solution. The phantom containers are shown in Fig. 1.

2.2. Quality control of MRI scanner

3T Siemens Magnetom Prisma MRI was used in this study. The accuracy of MRI scanner was checked by the quality assurance (QA) techniques suggested by Siemens corporation to ensure that the results are not affected by magnetic field inhomogeneity or other problems of single-voxel spectroscopy (SVS) measurements. The quality control was performed using Siemens MRS phantom which is a spherical phantom consisting of 8.2 g of $NaC_2H_3O_2$ and 9.6 g of $C_3H_3O_3$ per 1000 g of water. The phantom was placed inside the head coil, and the quality control sequences of Siemens scanner were applied. These sequences consist of point-resolved spectroscopy (PRESS) and stimulated echo acquisition mode (STEAM) with times of echos of 30, 135, and 270 ms for PRESS

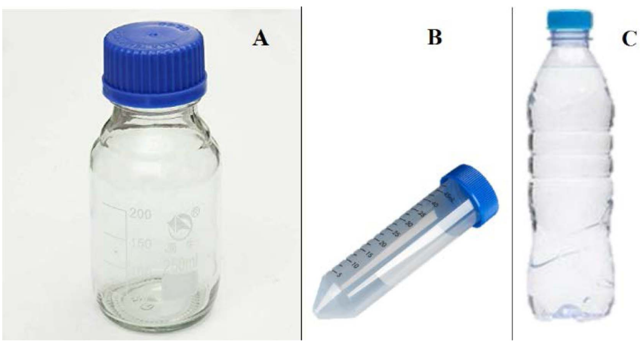

Fig. 1. (Color online) The containers that was used as MRS phantom. (A) clear laboratory glass, (B) falcon tube made of poly ethylene, (C) the bottle of mineral water made of poly-ethylene terephthalate (PET).

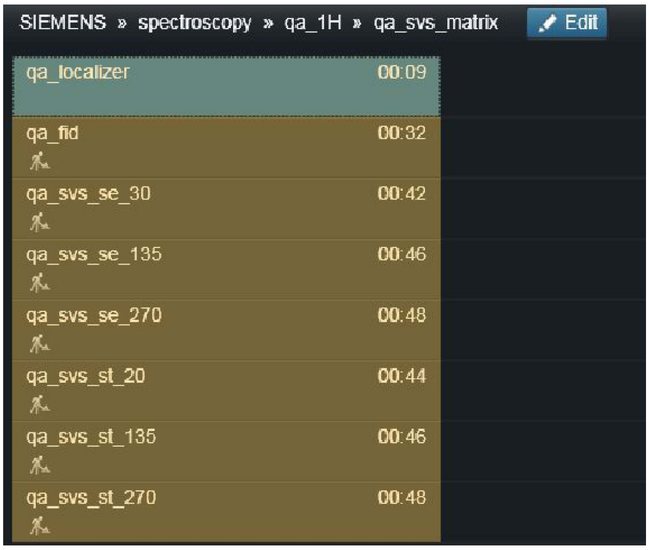

Fig. 2. (Color online) Dedicated pulse sequences for quality assurance in Siemens MRI scanner. qa = quality assurance, SVS = single voxel spectroscopy, fid = free induction decay, se pulse sequences are PRESS and st pulse sequences are STEAM.

and 20, 135, and 270 ms for STEAM (Fig. 2).

The first step of QC was evaluation of free induction decay (FID) raw data which assess the homogeneity of magnetic field across the phantom or quality of shim [18]. Qa_fid sequence (Fig. 2) was used for this assessment. This sequence evaluates the full width at half maximum (FWHM) of water signal.

The second step of the QA is the QA of localized SVS measurements. Other sequences in Fig. 2 were used for

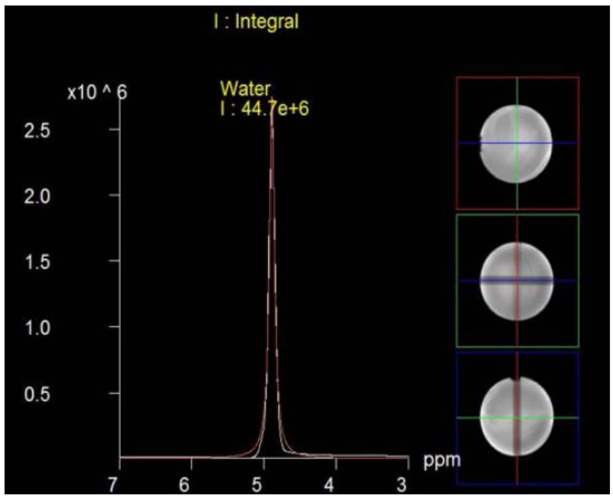

Fig. 3. (Color online) The results of the quality of shim or fid raw data (white line) in comparison to the standard result (red line). The FWHM of water signal was 20.1 Hz.

this assessment. In these measurements, the peak of acetate and lactate can be seen easily. The acetate and lactate peaks should be in phase in all STEAM pulse sequences and in PRESS pulse sequences should have inverted phase only in the TE of 135 ms.

2.3. Spectroscopy

MRS was performed for all three phantoms, using PRESS pulse sequence, TE of 135 ms, TR of 1500 ms and voxel size of 1.5×1.5×1.5 cm^3. Because of the small size of the falcon tube, the voxel size of fewer than 2×2×2 cm^3 was used. The FWHM and SNR of Cho and both peaks of Cr (Cr1 and Cr2) were calculated.

3. Results

Figure 3 shows the result of assessment of the quality of shim or fid raw data. The FWHM of the peak was 20.1 Hz. The results of the localized SVS QA measurements are shown in Fig. 4. Figures 5 to 7 show the spectra of the metabolites inside the laboratory glass, PET, and falcon tube. The results of FWHM and SNR of Cho, Cr1, and Cr2 peaks in all the three phantoms are shown in Table 1.

4. Discussion

The material of the phantom container is one of the

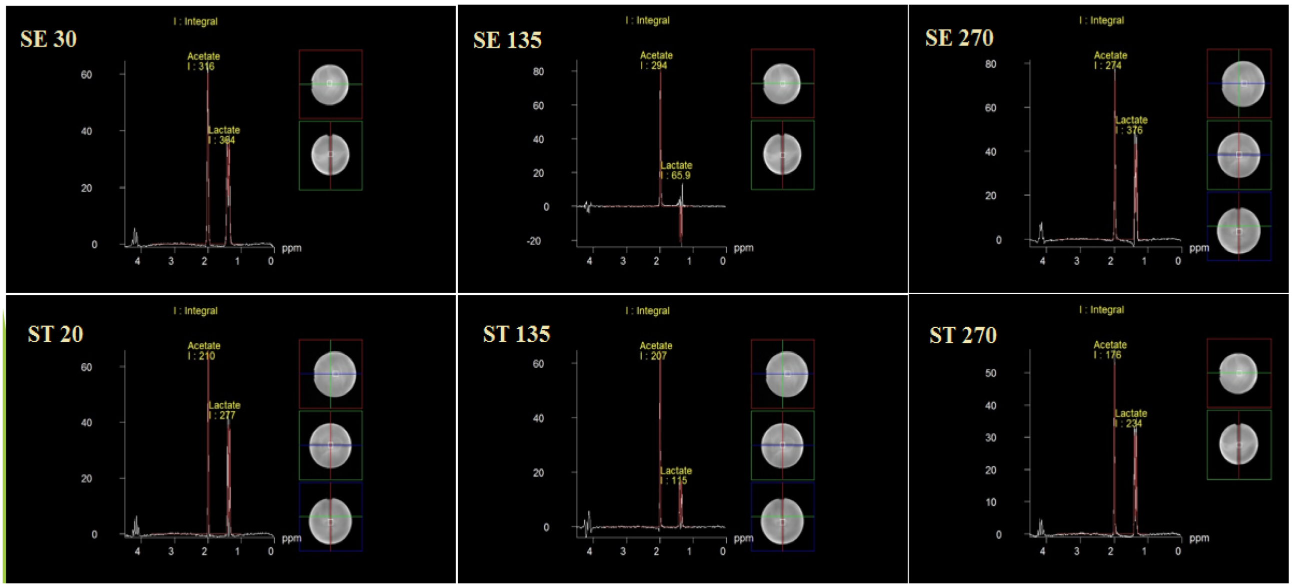

Fig. 4. (Color online) The results of localized QA SVS measurements. Upper row) The spectra provided by PRESS pulse sequence with TEs of 30, 135, and 270 ms. Lower row) The spectra provided by STEAM pulse sequence with TEs of 20, 135, and 270 ms.

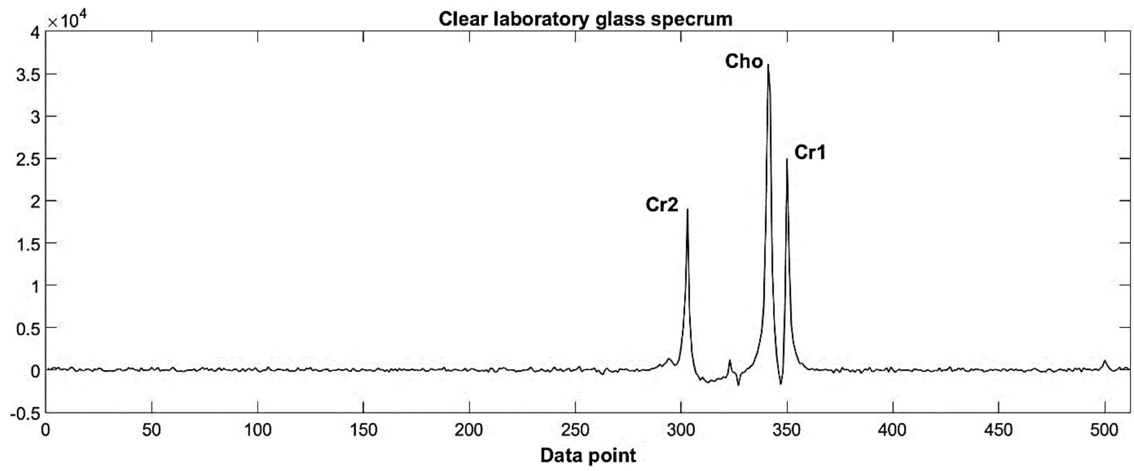

Fig. 5. Spectrum of metabolites (Cho, Cr including Cr1 and Cr2) inside clear laboratory glass phantom. There is a small baseline noise.

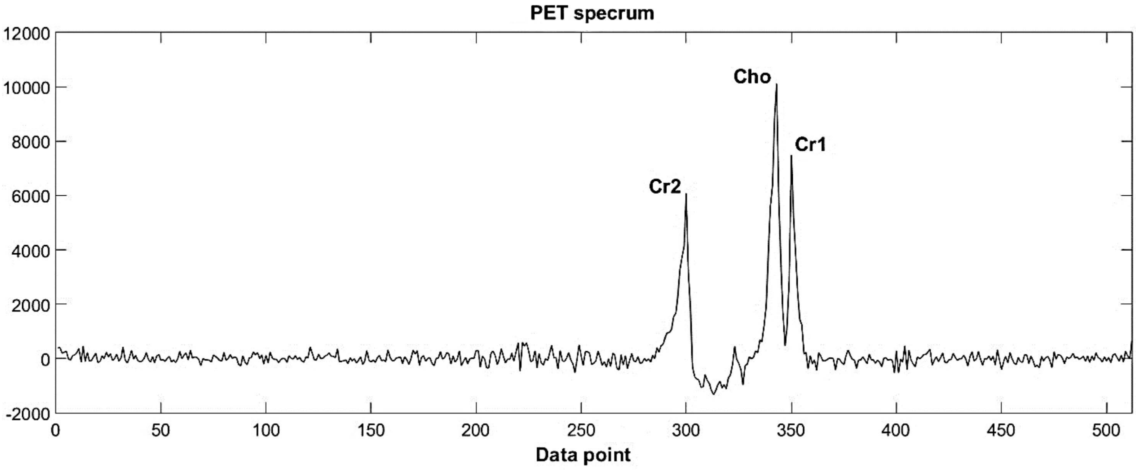

Fig. 6. Spectrum of metabolites (Cho, Cr including Cr1 and Cr2) inside the phantom of bottle made of PET. Baseline noise is more than spectrum provided by laboratory glass.

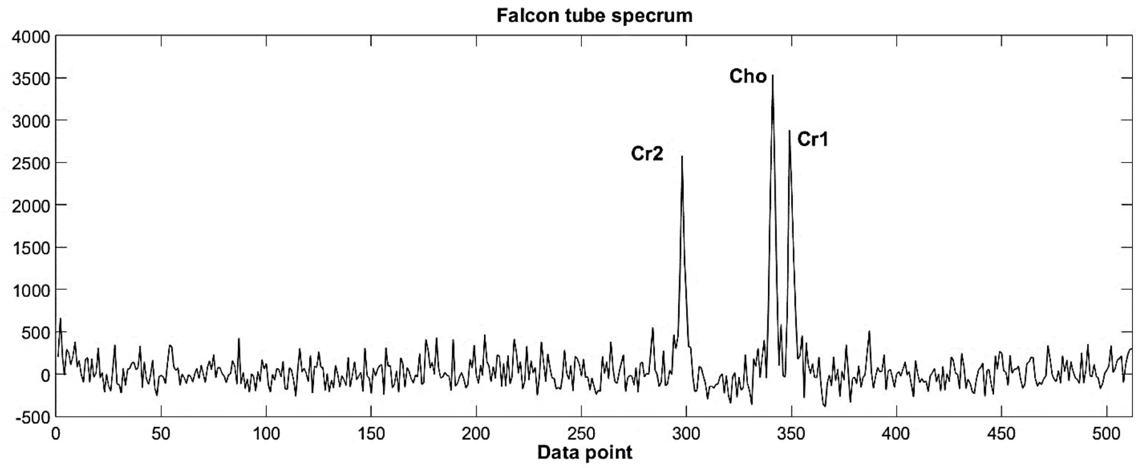

Fig. 7. Spectrum of metabolites (Cho, Cr including Cr1 and Cr2) inside the falcon tube. Baseline noise is more than spectrum provided by laboratory glass and PET phantoms.

important parameters in the design and construction of the phantom since the small number of impurities can affect the baseline noise, SNR, and FWHM of the peaks. The effect of material impurities during the imaging with 1.5 MRI scanner can be severe to the extent that it might destroy the signal [16]. In this study, the effect of the phantom container material was assessed in 3T MRI scanner using three phantoms made of laboratory glass, PET, and polyethylene that were filled by Cho and Cr.

QA of MRI scanner before these studies is very important to prevent the effects of disturbing factors. According to the spectroscopy operator manual of Siemens in a 3T MRI scanner, FWHM should be less than 30 Hz. Based on Fig. 3, the obtained FWHM of water signal was 20.1

Table 1. FWHM and SNR of Cho and Cr peaks provided by glass, PET, and falcon phantoms.

Phantom material / Metabolites	Laboratory glass		PET		Falcon tube	
	FWHM (Data points)	SNR	FWHM (Data points)	SNR	FWHM (Data points)	SNR
Cho	2.50	286.05	5.18	53.21	2.73	22.00
Cr1	2.08	197.70	2.96	47.70	2.73	17.92
Cr2	1.70	150.81	4.44	38.75	2.34	16.03

Hz.

For localized SVS QA measurements, it was expected that the acetate and lactate peaks should be in phase in all STEAM pulse sequences and in PRESS pulse sequences should have an inverted phase only in the TE of 135 ms. In Fig. 4, the peaks of acetate and lactate had an inverted phase as it was expected. Therefore, according to the results of QA, the spectra provided by the scanner are accurate.

According to Figs. 5 to 7, it can be observed that the signal of glass phantom had a cleanest baseline and narrowest peaks in comparison to PET and falcon tube phantoms. Based on Table 1, FWHM of all the peaks of the spectra provided from glass phantom was by average 50.08 and 19.48 % fewer than those provided by PET and falcon tube phantoms, and the SNRs of the all those of the spectra provided from PET and falcon tube phantoms were by average 77.99 and 91.18 % fewer than the peaks provided by glass phantom. This result is consistent with those of the previous study which concluded that pure glass can be a suitable material for phantom containers [16].

The signal of PET phantom had fewer baseline noise in comparison to the falcon tube; however, the peaks of PET phantom are broader than the other phantoms. FWHM of the all the peaks of the spectra provided from PET phantom was by average 38.00 % more than the peaks provided by falcon tube phantom, However, its SNR was by average 59.94 % more than the falcon tube. The spectrum of falcon tube had more baseline noise, but narrower peaks in comparison to PET phantom. The SNR of the peaks of PET phantom was more than the falcon tube since the baseline noise of the PET phantom spectra was less than the falcon tube. The spectrum of falcon tube phantom had more baseline noise because of the small size of the phantom; therefore, the walls of the phantom were close to the spectroscopy volume, so that it might affect the baseline noise. However, the peaks of falcon tube phantom were narrower than the PET phantom since its container contained fewer impurities in comparison to the PET phantom. The peaks of PET phantom were broader than those of the other phantoms due to the impurities that exist in the phantom container. Some additives are added to the PET material during the polycondensation such as germanium, antimony, titanium, magnesium, zinc, and cobalt. Some other materials produce and add to the PET during prepolimerization such as bis(hydroxyethyl) terephthalate [19]. These impurities can affect the magnetic field and cause peak broadening [16].

There are other reconstruction algorithms such as fast pade transform that can be used instead of the fast furrier transform to reduce the noise and increase the signal to noise ratio which makes the quantization easier in the presence of background noise [20]. Probably, the use of this method can reduce the noise of the spectra provided by the phantom containers that contain impurities. It is a new method that requires more research.

5. Conclusion

From the results, it can be concluded that the laboratory glass is a good material for building home-made MRS phantoms since it does not affect the baseline noise, FWHM, and SNR of the spectra. It was also revealed that the size of the phantom and the distance between the spectroscopy volume and phantom walls are important and can affect the baseline noise. It is also proved that the present impurities in the material of phantom container can affect the spectra provided by 3T MRI scanner. This impact might not be that much severe to destroy the spectrum, but it can cause peak broadening; in complex spectra containing a lot of metabolites, this makes the quantization difficult or impossible.

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