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Can we use ^{1}H MRS shimming values to obtain ^{31}P spectra?

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Abstract—**The perfect shimming of ^{31}P magnetic resonance spectroscopy (MRS) is not easy in vivo. The purpose of this study was to examine the feasibility of using ^{1}H MRS shimming values to obtain ^{31}P spectra in a same sequence. Both phantom and volunteer studies were carried out in this study. Phantom was a sphere filled with physiological metabolites of brain. In vivo study was performed on 4 healthy volunteers. The studies were performed on a 3-T GE scanner. A same localizer and a same cursor were used for both ^{1}H and ^{31}P scans. A spin echo MRS sequence was utilized for both ^{1}H scans with a standard head coil and ^{31}P scans with a GE service coil. ^{1}H scan was performed using first and automatic shimming and water linewidth (FWHM) of 3 Hz for phantom and 5 Hz for the volunteer were obtained. Shimming values of ^{1}H scan in x, y, z directions were copied to ^{31}P scan. A routine procedure of ^{31}P scan without value coping was also performed. Spectra were analyzed using SAGE/IDL program. Signal to noise ratio (SNR) was defined as the ratio of the signal height / maximum noise height. Good ^{1}H spectra and ^{31}P spectra were obtained for both phantom and volunteer studies. The ^{31}P spectra with ^{1}H MRS shimming values were similar with the ^{31}P spectra obtained with routine procedure. Lower SNRs of ^{31}P spectra were obtained in phantom with ^{1}H MRS shimming values, compared with routine procedure scan. Average SNR for Pi of ^{31}P spectra was 7.45:1 in the volunteer study with routine procedure, and 7.275:1 with ^{1}H MRS shimming values. ^{1}H MRS shimming values can be used to obtain useful ^{31}P spectra in a same sequence.**

I. INTRODUCTION

The advantage of using ^{31}P magnetic resonance spectroscopy (MRS) over sample metabolic analyses arises from its non-invasive nature, and continuous spectra to be obtained from tissue in real-time. ^{31}P MRS can provide important information on energy metabolism concerning such factors as phosphocreatine (PCr) and adenosine triphosphate (ATP) concentrations, intracellular pH, and rate constant of creatine kinase (CK) reaction, etc. ^{31}P MRS has been utilized in many organs and tissue of human body.

Unlike ^{1}H MRS where strong water signal is a good reference for shimming, in vivo ^{31}P MRS has no any strong signal as a good reference for shimming. In stead, useful metabolite signals are often difficult to be detected from the beginning of ^{31}P MRS procedures. The perfect shimming of ^{31}P magnetic resonance spectroscopy (MRS) is not easy in vivo[1,2]. It has been an acceptable procedure that ^{1}H MRS shimming is performed before ^{31}P MRS procedure and ^{1}H MRS shimming result is used in ^{31}P MRS[1-4]. However, the resonance frequency is different between ^{1}H MRS and ^{31}P MRS. We should study whether there is a big difference between ^{1}H MRS shimming and ^{31}P MRS shimming. The purpose of this study was to examine the feasibility of using ^{1}H MRS shimming values to obtain ^{31}P spectra in a same sequence.

II. MATERIAL AND METHODS

Both phantom and volunteer studies were carried out in this study. Phantom (Braino, General Electric Medical Systems) was a sphere filled with an aqueous solution including 50 mM potassium phosphate and 1 mlMagnevist (Berlex Laboratories,Wayne, NJ). In vivo study was performed on 4 healthy volunteers (3 male and 1 female, 27–46 years old). All procedures were approved by the research committee at the University of Toronto. All volunteers were from MR research team. The studies were performed on a 3-T GE scanner (General Electric Medical Systems, Milwaukee, WI). The phantom study was performed before volunteer study every time. A same localizer and a same cursor were used for both ^{1}H and ^{31}P scans. The localizer was obtained with a gradient each sequence. A spin echo MRS

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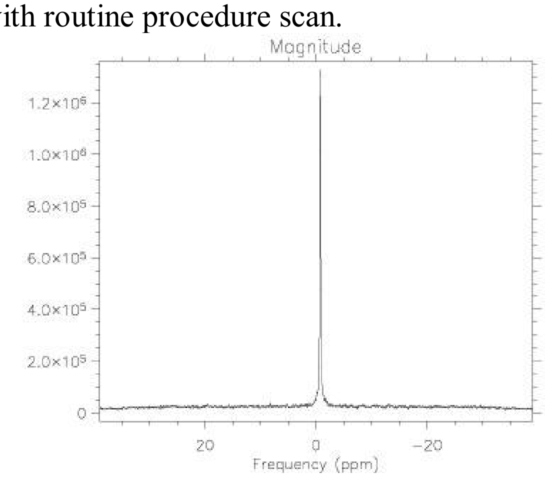
sequence was utilized for both ^{1}H scans with a standard head coil and ^{31}P scans with a GE service coil. TR 2000 msec and TE 35 msec were kept same for both ^{1}H scans and ^{31}P scans with 128 scan averages. ^{1}H scan was performed using first and automatic shimming and water linewidth (FWHM) of 3 Hz for phantom and 5 Hz for the volunteers were obtained. Shimming values of ^{1}H scan in x, y, z directions were copied to ^{31}P scan. The standard head coil was unplugged when ^{31}P scans were performed. A routine procedure of ^{31}P scan without ^{1}H value coping was also performed for both phantom and volunteer studies.

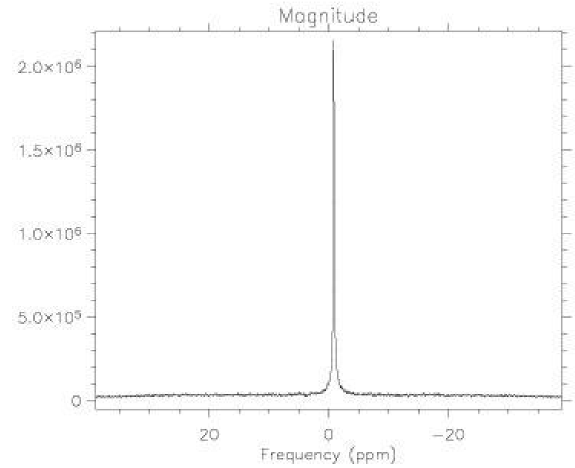
Data were processed offline using the SAGE/IDL software. Baseline and phase corrections were performed. The signal height of inorganic phosphor and maximum noise height were measured. Signal to noise ratio (SNR) was defined as the ratio of the signal height / maximum noise height[5].

III. RESULTS

Good ^{1}H spectra and ^{31}P spectra were obtained for both phantom and volunteer studies. The general quality of the ^{31}P spectra from phantom is shown in Fig. 1. Figure 1A displays the ^{31}P spectra with ^{1}H scan value coping and Figure 1B without ^{1}H scan value coping. In general, the quality of ^{31}P spectra without ^{1}H scan value coping was better than the ^{31}P spectra with ^{1}H scan value coping. Lower SNRs of ^{31}P spectra were obtained in phantom with ^{1}H MRS shimming values, compared with routine procedure scan.



A



B

Fig. 1. Figure 1A was 31p spectra with 1H value coping. Figure 1B was 31P spectra without 1H value coping. B is better than A

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The ^{31}P spectra obtained with ^{1}H MRS shimming values were similar with the ^{31}P spectra obtained with routine procedure in volunteer studies. An example of the ^{31}P spectra from a volunteer is shown in Fig. 2. Figure 2A displays the ^{31}P spectra with ^{1}H scan value coping and Figure 2B without ^{1}H scan value coping. From visual inspection, there is no big difference concerning quality. Average SNR for Pi of ^{31}P spectra was 7.45:1 in the volunteer study with routine procedure, and 7.275:1 with ^{1}H MRS shimming values. Table 1 summarizes the detail numbers.

Table 1. SNRs for Pi of phantom and volunteer studies

	phantom		volunteer	
	with	without	with	without
1	36.7:1	59.2:1	7.3:1	7.5:1
2	42.4:1	63.3:1	6.5:1	6.1:1
3	34.6:1	55.7:1	7.4:1	7.6:1
4	37.5:1	61.9:1	7.9.1	8.6:1
mean	37.8:1	61.9:1	7.275:1	7.45:1

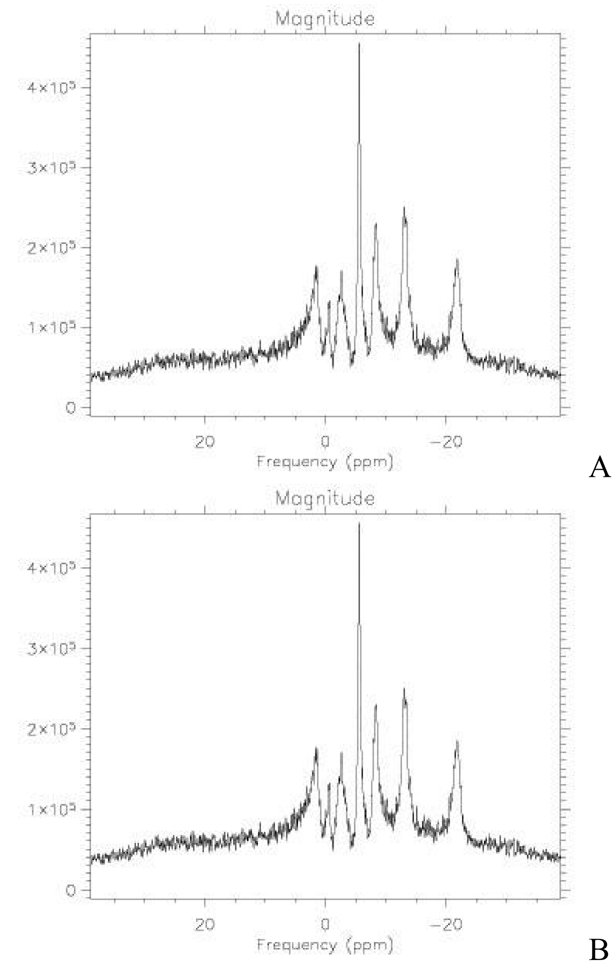

Fig.2. Figure 2A was ^{31}p spectra with ^{1}H value coping. Figure 2B was ^{31}P spectra without ^{1}H value coping. B is similar with A

IV. Discussion

Spectral resolution is determined primarily by three factors. First, the transverse relaxation time (*T*2) of the metabolite is inversely proportional to the ideal peak width. Second, the *B*0 separation between peaks ~in Hz! increases linearly with magnetic field strength. Third, the local magnetic field inhomogeneities widen and distort the spectral lines from their ideal Lorentizian forms. Maximum homogeneity is accomplished by adjusting DC currents in the gradient coils and room temperature shim coils. The name for this process is ''shimming''. [6] From our studies, we noticed that ^{31}P spectra obtained with ^{1}H MRS shimming values were similar with the ^{31}P spectra obtained without 1H values in volunteer studies. The difference of resonance frequency seems not an important issue. ^{1}H MRS shimming values can be used to obtain useful ^{31}P spectra in a same sequence.

In clinical works, useful metabolite signals are often difficult to be detected from the beginning of ^{31}P MRS procedures. The perfect shimming of ^{31}P MRS is not easy in vivo. In order to solve this problem, many efforts have been made previously. One effort is to use double-tuned coils. A high signal-to-noise ratio (SNR) in ^{31}P MRS can be obtained only with good B0-field homogeneity and optimal coil sensitivity. This demands double-tuned coils with a highly sensitive 31P channel and an additional 1H channel for 1H-magnetic resonance imaging, shimming, 1H decoupling, and nuclear Overhauser enhancement (NOE). A comparison with conventional, single-tuned coils shows that, in spite of double tuning, there is no significant loss in ^{31}P sensitivity while the ^{1}H channel provides the requested performance.[1-2, 7-9] But great effort is needed to build the coil if the commercial double-tuned coils are not wealth while.

V. Conclusion

The purpose of this study was to examine the feasibility of using ^{1}H MRS shimming values to obtain ^{31}P spectra in a same sequence. Both phantom and volunteer studies were carried out in this study. Our results shown that the ^{31}P spectra with ^{1}H MRS shimming values were similar with the ^{31}P spectra obtained with routine procedure in volunteer studies. ^{1}H MRS shimming values can be used to obtain useful ^{31}P spectra in a same sequence.

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