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Theodoros N. Arvanitis
Des Watson

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Theodoros N. Arvanitis
Graduate Division of Biomedical Engineering
University of Sussex, Falmer, Brighton, BN1 9QT, UK
Email: theoa@cogs.susx.ac.uk

Des Watson
School of Cognitive & Computing Sciences
University of Sussex, Falmer, Brighton, BN1 9QH, UK
Email: desw@cogs.susx.ac.uk

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Abstract

This research paper presents the problem of respiratory motion and the associated artefacts in Magnetic Resonance Spectroscopy. The nature and the appearance of respiratory motion artefacts, already extensively investigated in conventional 2D Fourier transform Magnetic Resonance Imaging, is studied in combination with the possibility of using the ROPE (Respiratory Ordered Phase Encoding) method to reduce such artefacts. In particular the study is focused on spectroscopic CSI and processing of the data is done by using the autocorrelation function.

This paper is given as originally presented, in the form of scientific poster at the SMRM 12th Annual Meeting, New York 14-27, August, 1993, with the title: "An Investigation of motion artefact in spectroscopic CSI" by T. N. Arvanitis, D. J. Bryant[1], A. G. Collins[1], G. A. Coutts[1], and A. S. Hall[1]. (The original abstract can be found in the Proceedings of the SMRM 12th Annual Scientific Meeting, August 1993, volume 2, p909).

[1]Robert Steiner NMR Unit, Hammersmith Hospital, Du Cane Road, London W12 0HS, UK

Introduction

The appearance of artefacts due to physiological motion is commonly recognized in conventional 2D Fourier transform imaging. Motion introduces signal modulation resulting in displaced "ghost-like" artefacts and an overall degradation of image quality.

The development of multi-dimensional spectroscopic chemical shift imaging (CSI) has particularly emphasized the degree of spatial localization. However, despite its applications to hepatic and cardiac spectroscopy, the relevance of movement upon CSI has not been fully investigated.

Aim of the Study

In this work, we investigate the effects of physiological motion upon spectroscopic CSI data, as well as the possibilities of correcting these effects by using ordered phase encoding techniques for the acquisition of the data. In particular, we investigate the application of the Respiratory Ordered Phase Encoding (ROPE) method [1] to the acquisition of CSI data.

Furthermore, we use the autocorrelation function of the spectroscopic data as an attempt to specify a standard approach to the quantification of the relative contributions of ghosting and noise, in order to assess improvements in motion artefact control.

Materials and Methods

All experimental work was carried out on a Picker prototype MRS system, operating at a field strength of 1.5 Tesla. Enveloping transmitter coils were employed in order to generate homogeneous excitation fields. Surface receiver coils were employed to improve sensitivity. The overall configuration represents one of the standard protocols for our own *in-vivo* hepatic MRS studies [2].

A phantom was constructed [3] consisting of a cylinder (height 10 cm, diameter 5 cm), filled with $CuSO_4$ solution. A mechanical coupling applied periodic vertical displacement to the phantom with an amplitude and period which could be varied to model the effects of human respiratory motion.

2D CSI was employed throughout the study. In order to maintain higher levels of potential motion artefact we have avoided averaging each phase encoding step [4]. Sensitivity was improved by sampling larger data matrices of 256 or 128 lines with 1 or 2 averages of each line. This contrasts with our *in vivo* MRS protocols where typically each of 16 lines would be accumulated 16 times.

The experimental images were acquired by using conventional 2D-FT spin echo imaging sequences.

For the implementation of ROPE, the motion waveform was digitized to 256 levels and was sampled for a short period prior to the commencement of each scan. As the scan proceeded, 30 ms before each phase encoding pulse, the respiratory amplitude was measured and an appropriate phase encoding gradient applied.

For the *in vivo* studies, ^{31}P or ^{1}H water/fat spectra were collected from volunteers, with the same configuration.

Results

Figures 1 and 2 show a comparison of an identical slice in a volunteer cardiac ^{31}P spectroscopic study, where the data is acquired with and without the use of ROPE, displaying a clear difference in the noise character and the lack of any strong bogus resonances. In neither of the datasets this comparison do planes outside the body of the volunteer contain any obvious ghost spectrum.

Overall, we have found that ^{31}P ROPE data acquisitions show increased sensitivity (5-10 %), which is mostly associated with decreases and changes of the noise pattern. This advantage is often unclear because of the intrinsic low SNR of ^{31}P spectra.

Figures 3 and 4 show a comparison of an identical slice in a volunteer hepatic ^{31}P MRS study, where the data is acquired with and without ROPE respectively. In this case, the ROPE spectrum displays an improved SNR as well as control of bogus resonances observed in the non-ROPE spectrum.

Our experimental spectroscopic data, acquired from the moving phantom. has been analysed by the use of an autocorrelation function algorithm. Figures 5-10 display the images and the corresponding autocorrelation functions (performed in the phase encoding direction) from the static (figures 5 and 6), moving (figures 7 and 8) and ROPE (figures 9 and 10) spectroscopic data from the motion phantom.

Discussion

Our *in vivo* data have shown that motion artefact can be manifest as a redistribution of noise and displaced resonances, which can, to some extent, be controlled by ROPE.

The autocorrelation function of the moving phantom compared with that of the static phantom, although not showing a clear structure, displays higher order correlations arising from the ghosting, which disappear in the ROPE data.

It is hoped that this method will provide further information about the noise distribution and allow quantitative assessment of the motion artefact reduction schemes applicable to CSI data.

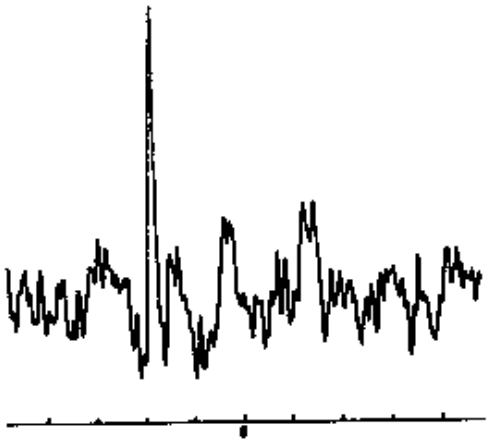

Figure 1: Non-ROPE ^{31}P cardiac spectrum

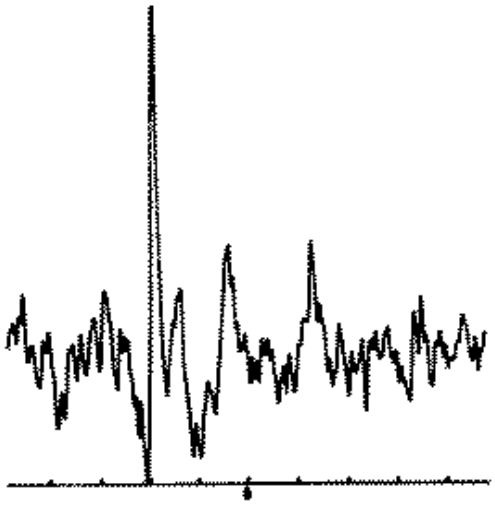

Figure 2: ^{31}P cardiac spectrum with ROPE applied

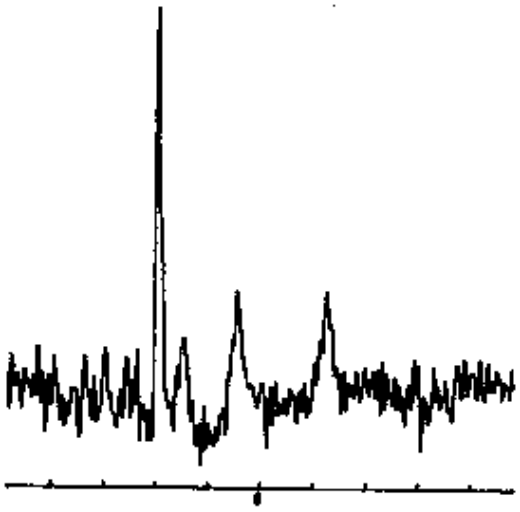

Figure 3: ^{31}P hepatic, non-ROPE MRS spectrum - surface plane

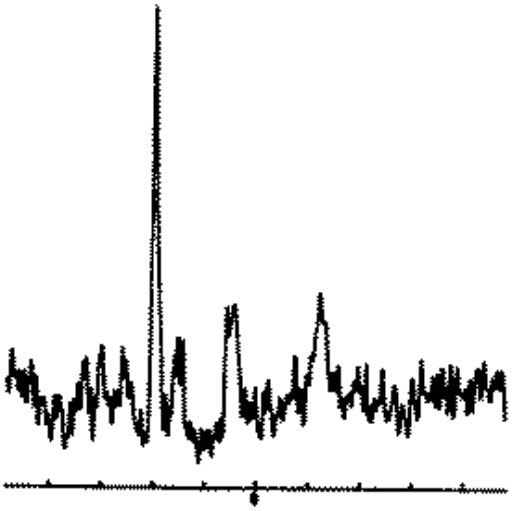

Figure 4: ^{31}P hepatic study with ROPE acquisition - surface plane

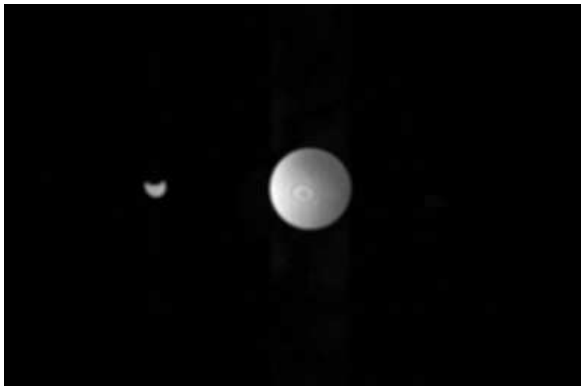

Figure 5: MR image of stationary phantom

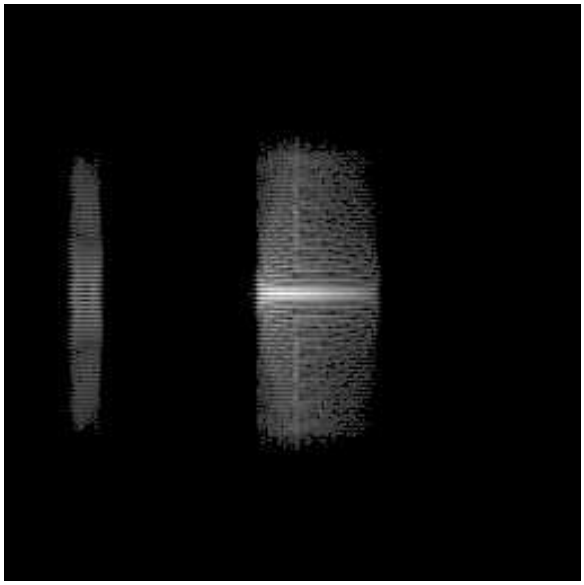

Figure 6: Autocorrelation in phase encode direction of stationary object

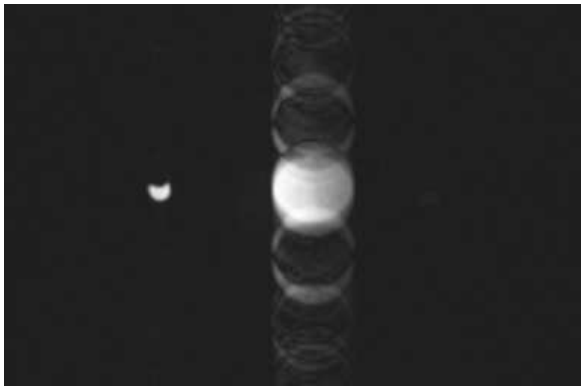

Figure 7: MR image of moving phantom

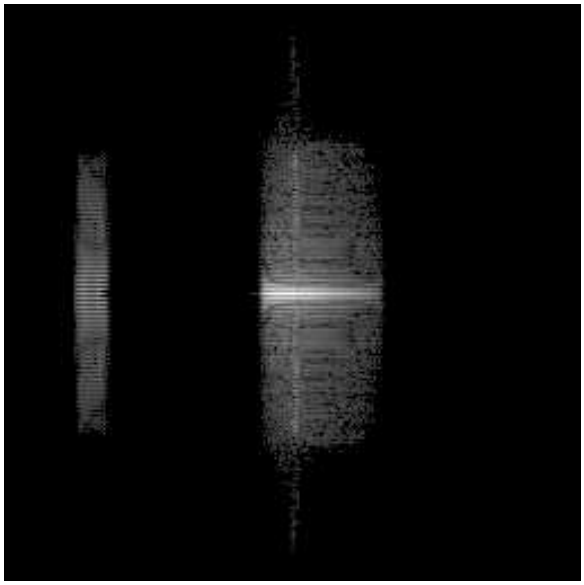

Figure 8: Autocorrelation in phase direction of moving object

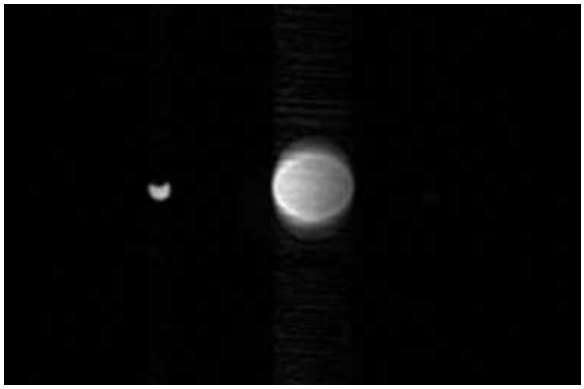

Figure 9: MR image of moving phantom with ROPE acquisition

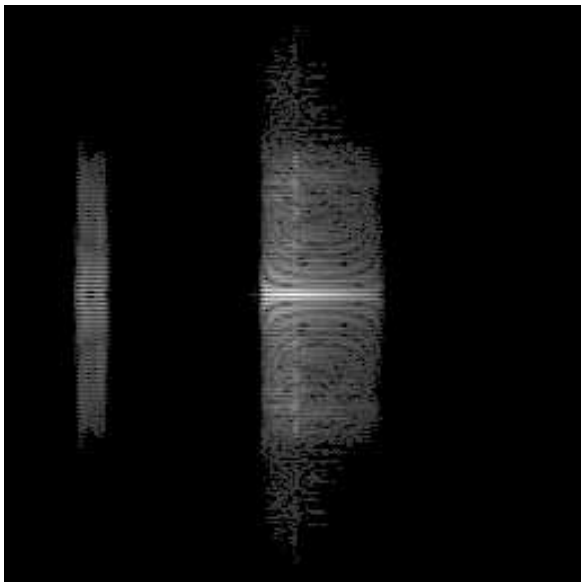

Figure 10: Autocorrelation function in phase encode direction for moving object with ROPE acquisition

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Acknowledgments

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