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Cancer with Phosphorus-31 Magnetic Resonance

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13. Abstract (Maximum 200 Words) (abstract should contain no proprietary or confidential information) The objective of the proposed research is to develop 1H-decoupled 31P magnetic resonance spectroscopy (MRS) techniques for measuring non-invasively the response of breast cancer to induction or preoperative chemotherapy. We hypothesize that the quantitative assessment of the effectiveness of a treatment using 31P MRS will be clinically feasible at 3.0T. During this reporting period, a double tuned breast RF coil was built and tested. The coil was based on a commercial coil body, and tuning elements appropriate for the 3.0 T field strength were installed. The clinical scanner, nominally designed as a proton-only instrument, was converted to operate on the phosphorus frequency by suitable modification of the transmitter and receiver electronics. The coil may therefore be used to obtain proton scout images, and then switched to phosphorus for reception of spectra.				
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INTRODUCTION

Advances in the understanding of the biology of breast cancer are leading to the identification of novel therapeutic targets, the development of new cytotoxic agents and strategies for treatment of this disease. The identification of suitable early markers of tumor response to a specific chemotherapeutic agent will make it possible to customize an effective treatment for each patient, rejecting ineffective drugs early in treatment, and tailoring the regimens of effective agents for optimum response. Phosphorus-31 (^{31}P) magnetic resonance spectroscopy (MRS) can provide information non-invasively on alterations in tumor metabolism caused by chemotherapy in women with breast cancer. Thus, the objective of the proposed research is to develop ^{31}P MRS techniques for measuring noninvasively the response of breast cancer to induction or preoperative chemotherapy. To validate our approach, we will perform first, measurements using appropriate standards and, second, a pilot study of women with breast cancer undergoing induction chemotherapy.

BODY

The Siemens 3.0 T whole body clinical MR scanner installation required by this study was severely delayed; the installation was not completed until the current calendar year. As a result a no cost extension to the project was requested and granted. The original principal investigator, Dr. Garrido, has left the institution, but remains as a consultant to the project. Dr. Jerome Ackerman has been appointed principal investigator to continue and complete the project.

The RF coil to be used in the pilot study was constructed and tested for ^{31}P spectroscopy. This coil is based on a commercial breast coil mechanical structure supplied by MRI Devices, Inc. No commercial manufacturer offers a proton/phosphorus breast coil, necessitating the construction of the coil as part of this project. The proton channel of the coil encompasses both breasts, and may be used to obtain scout images in order to localize the tumor. When used for ^{31}P spectroscopy, the coil encompassing each breast may be used singly for best filling factor and signal to noise ratio, while RF decoupling power is applied to the proton port. Please see Figure 1 for a photograph of the coil.

The scanner was modified to enable excitation and reception of ^{31}P signals. To accomplish this, the amplitude and phase modulated low power RF pulse as generated normally by the scanner at the proton frequency is intercepted at the point where it would normally enter the RF power amplifier. This proton frequency pulse is then mixed with a local oscillator signal provided by an auxiliary frequency synthesizer, low pass filtered to remove the incorrect frequency sideband, and amplified to yield an identically phased and shaped pulse, except at the ^{31}P frequency of 49.903 MHz. This ^{31}P pulse is fed into the RF power amplifier (which is broadband, and therefore capable of amplifying the pulse), and applied via a passive diode switched quarter wave duplexer to the RF coil. The received ^{31}P signal is amplified by a low noise (0.5 dB noise figure) narrowband GaAsFET preamplifier (Advanced Receiver Research, Inc.), fed to an additional gain stage, mixed with the local oscillator frequency back to the proton frequency, band pass filtered, and fed into the scanner's receiver. This permits the scanner to operate normally as if it were exciting and detecting protons, while it is actually exciting and detecting phosphorus. To best preserve the dynamic range of the received signal, a very high level (23 dBm) mixer is used on the receiver side. Switching between proton and phosphorus operation is accomplished with a simple change of cables in the scanner's instrument room and does not involve changes near the patient or magnet. The cable switching function is now

performed manually, but will be changed to remote operation by means of coaxial relays, so that the operator does not have to leave the console area. The schematic diagram of the frequency shifting circuitry is shown in Figure 2.

While this double resonance breast coil was being worked on, a prototype 3.0 T proton-only coil (but otherwise identical to the $^1\text{H} - ^{31}\text{P}$ coil) was obtained from MRI Devices (at no cost to this project) and tested on the scanner. A series of proton images (transverse and coronal localizer, multislice coronal T_2 -weighted turbo spin echo, coronal T_1 -weighted spin echo, coronal STIR) was obtained with this coil from a normal female volunteer to evaluate the 3.0 T proton breast imaging performance to be expected. A typical coronal T_2 -weighted turbo spin echo image slice appears in Figure 3. The image quality appears to be excellent, and should be roughly illustrative of the proton imaging performance of the double tuned version. However, the double tuned version will have somewhat lower proton performance, because it is specifically and strongly optimized for ^{31}P reception, while being more than adequate for proton localizer imaging.

KEY RESEARCH ACCOMPLISHMENTS

- Construction and ^{31}P testing of the double tuned $^1\text{H} - ^{31}\text{P}$ RF coil to be used in the pilot study
- Conversion of the MR scanner to acquire ^{31}P NMR spectra

REPORTABLE OUTCOMES

No reportable outcomes from this research have resulted yet.

CONCLUSIONS

The extensive delay caused by the lack of a suitable MR scanner has been overcome. The RF coil has been constructed, and the scanner has been converted to operate at the ^{31}P frequency for reception of phosphorus spectra. During the next period, the validation of RF coil performance, including SAR testing, will be completed and the patient studies will be performed.

REFERENCES

n/a

APPENDICES

n/a

PERSONNEL RECEIVING SALARY

Leoncio Garrido, Ph.D.

Christian T. Farrar, Ph.D.

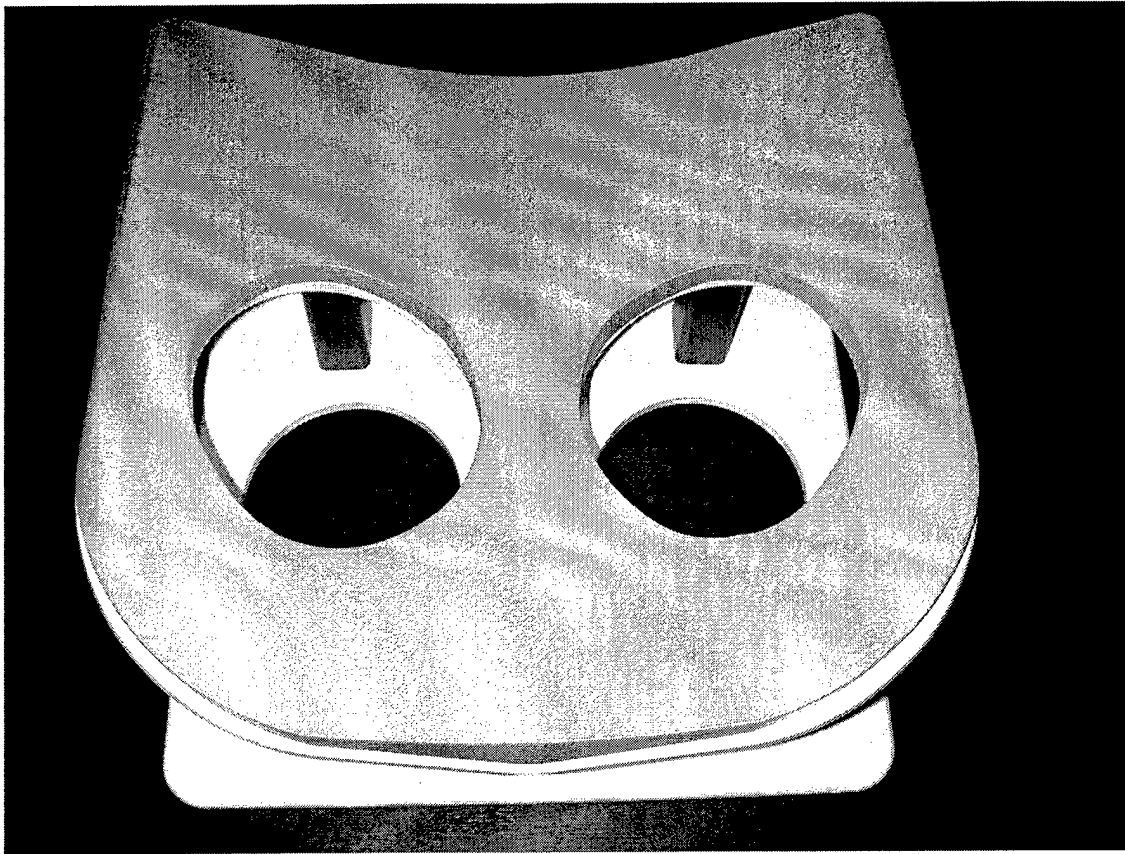


Figure 1. Photograph of the $^1\text{H} - ^{31}\text{P}$ double tuned breast coil as seen from the patient's view.

Figure 2. (Next page) Schematic diagram of the frequency shifting circuitry installed in the 3.0 T scanner to permit operation at the 49.903 MHz ^{31}P frequency. The proton operating frequency of the scanner is 123.274 MHz. The circuitry shifts the shaped and phased low power proton pulse to the ^{31}P frequency at 49.903 MHz, maintaining a net overall 0 dB gain, before the pulse is amplified by the scanner's broadband RF power amplifier (top line of left-to-right signal flow). The FID signal from the RF coil is amplified by a low noise preamplifier (bottom line), mixed back to the proton frequency, and fed into the scanner's receiver.

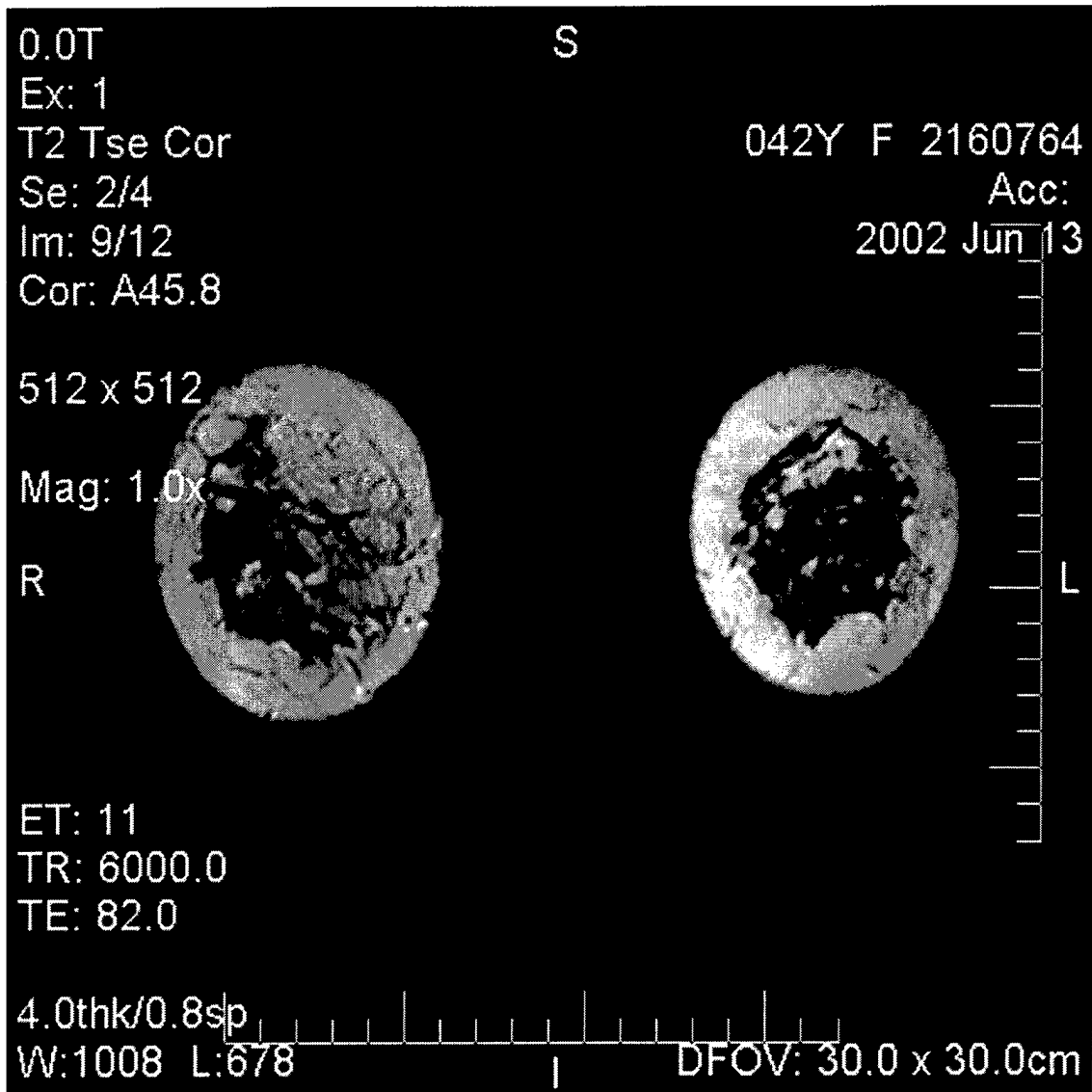


Figure 3. One slice from a coronal T₂-weighted turbo spin echo image series obtained on a normal volunteer from an equivalent (but proton-only) breast coil (same physical structure, but without the ³¹P tuning circuitry). The digital in plane resolution is 512 x 512 pixels, slice thickness 4 mm, field of view 30 cm, TR 6 sec, TE 82 msec.