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Development of a CEST MRI 3T Sequence for pH-Sensitive Imaging

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INTRODUCTION

- Chemical Exchange Saturation Transfer (CEST) MRI is a non-invasive contrast mechanism that probes proton exchange between labile proteins and water [1]
- Amide proton transfer (APT) imaging is a specific CEST technique that targets amide protons in endogenous mobile proteins, providing sensitivity to tissue protein content and pH changes [1-3]
- APT imaging has shown promising in-vitro and preclinical applications where pH-sensitive contrast may provide information beyond conventional MRI, however, robust pH and z-spectrum acquisition remains technically challenging due to acquisition efficiency [4,5]

OBJECTIVE

- To develop a novel CEST MRI technique at 3T for robust z-spectrum imaging, enabling enhanced quantitative pH-sensitivity

METHODS

- A **custom 3D Spoiled Gradient Echo (SPGR) sequence** was used to image pH effects. The sequence incorporated CEST preparation with an off-resonance Gaussian radio-frequency pulse and crusher gradient, Figure 1
- **Z-spectra were collected across logarithmically spaced frequency offsets from –7 to +7 ppm** on a 3T scanner (GE UHP) with a 48-channel head coil
- A **pH-sensitive phantom containing egg whites, water, and vinegar**, with pH values of 7.2, 6.8, and 6.4, was used to explore sequence performance [6]
- ROIs were placed inside each pH compartment for z-spectrum analysis and normalized signal intensities **(S_{sat}/S_0) were evaluated to examine pH-dependent contrast behaviour**
- PH mapping was performed using **MTR_{asym}, $(S_{sat(-\Delta\omega)}-S_{sat(+\Delta\omega)})/S_0$, via area under the curve (AUC) in the amide sensitive region, 400-500 Hz, and linear regression**

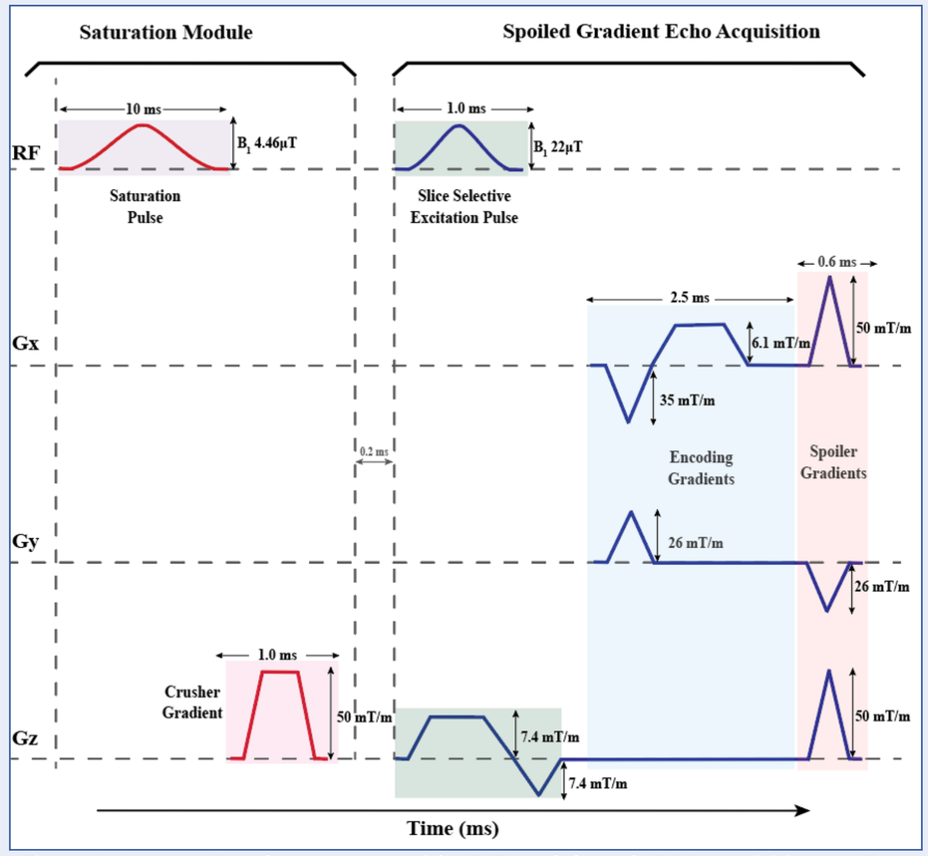
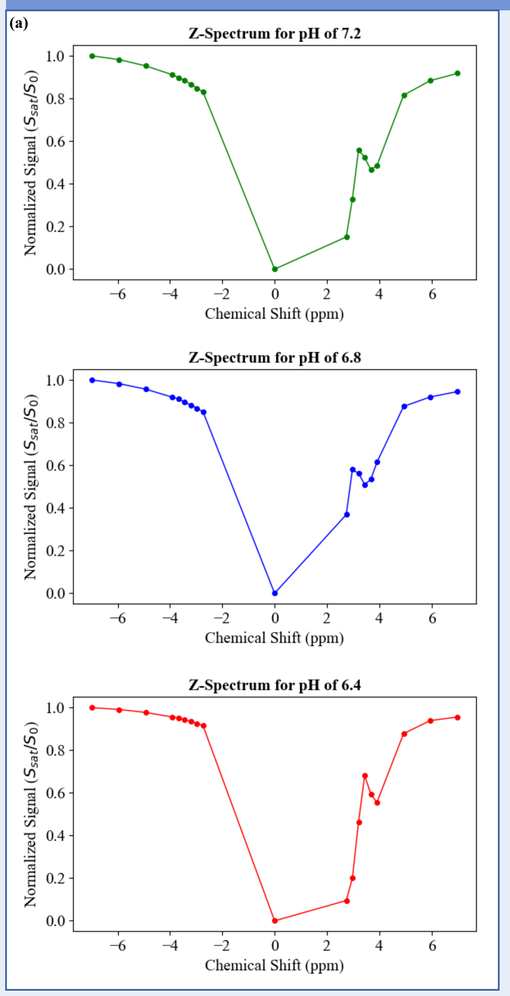
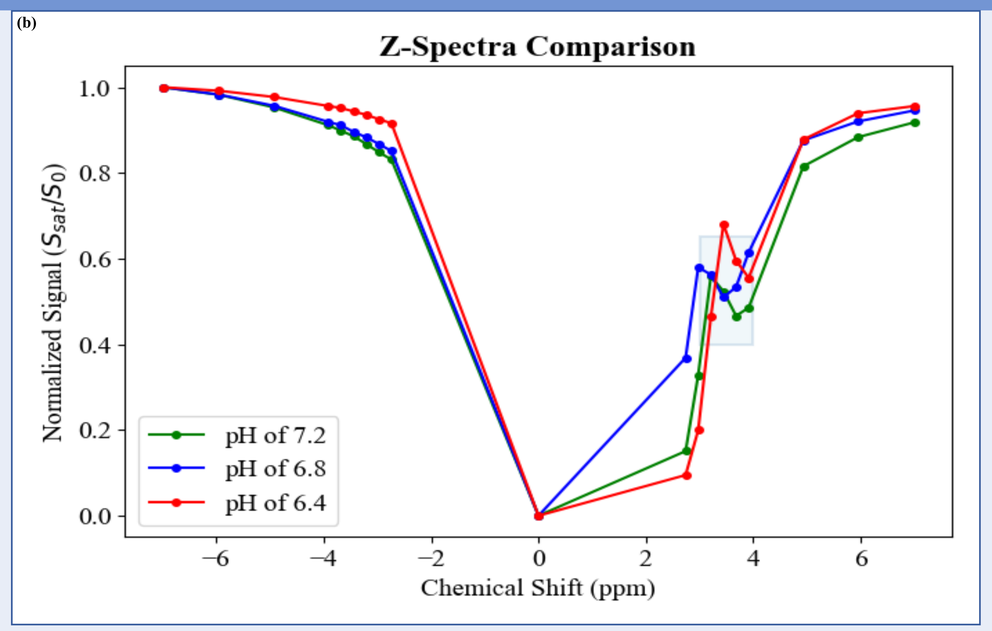


Figure 1. Custom 3D pulse sequence with CEST module and SPGR acquisition at 3T.

RESULTS





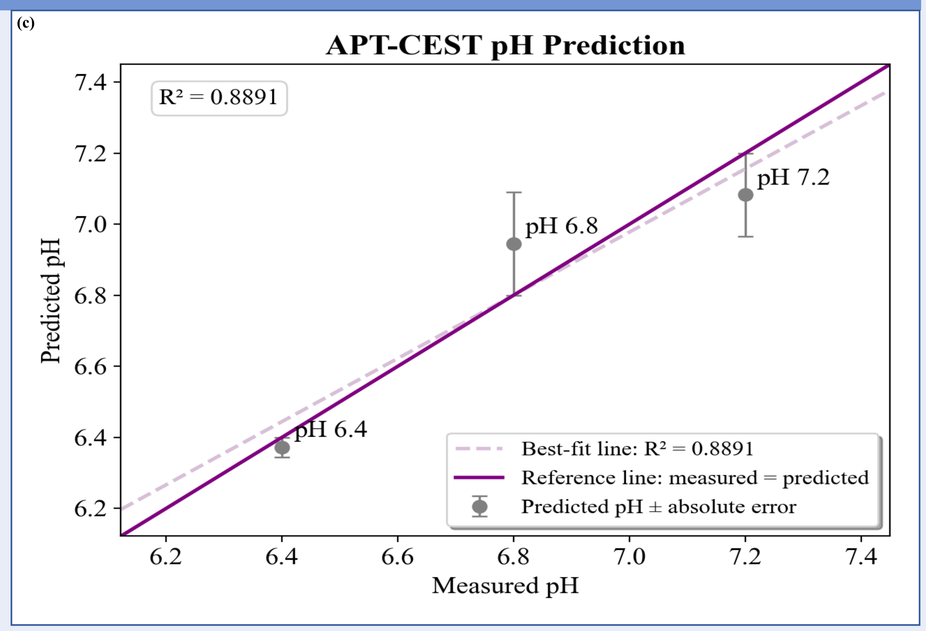


Figure 2. (a) Individual z-spectra for pH 7.2, 6.8, and 6.4 compartments. (b) Overlay of normalized z-spectra showing pH-dependent contrast differences. (c) Predicted versus measured pH using amide AUC-based linear regression.

DISCUSSION

- The custom 3D SPGR CEST sequence g**enerated measurable pH-dependent z-spectrum differences across the phantom compartments, Figure 2**
- Amide region AUC provided a quantitative feature for pH estimation, with preliminary calibration showing a **strong linear relationship with measured pH values, R^2 = 0.8891**
- **Linear regression predicted phantom pH with low error across compartments**, with predicted values of 7.16, 6.87, and 6.38 for measured pH values of 7.2, 6.8, and 6.4, respectively. Mean absolute pH error was 0.097 and maximum absolute error was 0.145 pH units

CONCLUSION

- By targeting labile proton exchange within a physiologically relevant pH range, the sequence may support **future non-invasive evaluation of tissue acidosis after validation in biological tissue or in-vivo models**
- The **modular design can incorporate acceleration strategies** such as compressed sensing and/or parallel imaging, providing a flexible platform for volumetric or time-resolved pH-sensitive MRI [7]

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