Simultaneous ^{19}F MR EPI imaging and near-infrared spectroscopy to establish correlations in tumor oxygen dynamics

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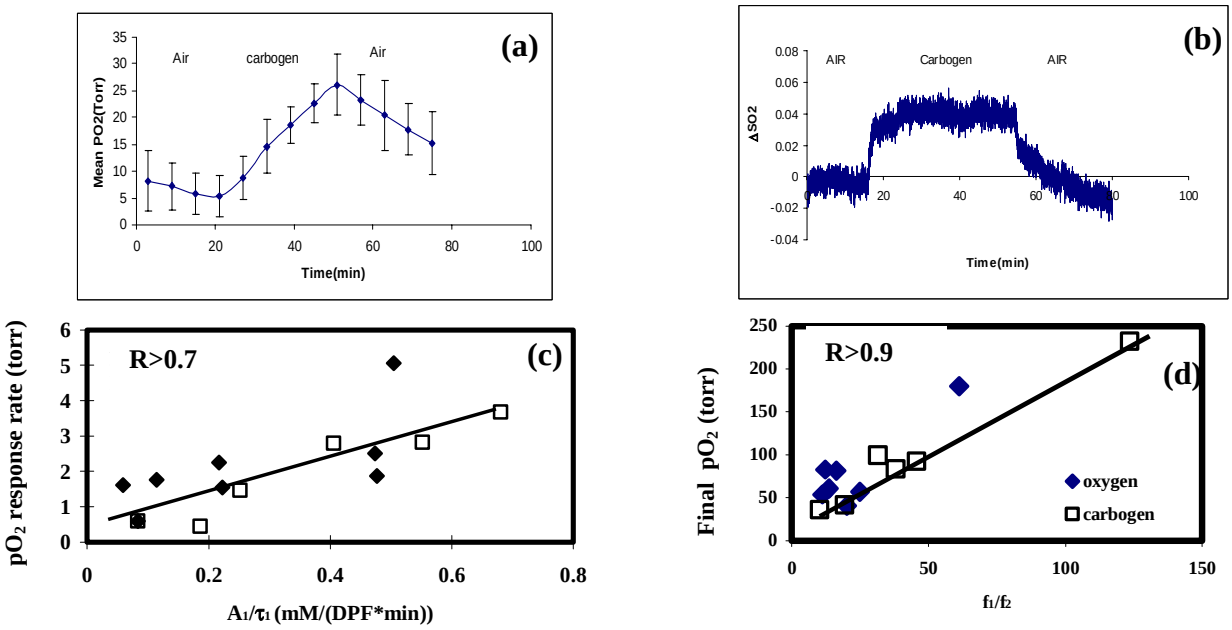
Background: Tumor oxygenation is recognized as a crucial factor governing the efficacy of radiotherapy. Accordingly, accurate evaluation of tumor oxygenation could provide a better understanding of tumor response to therapy. Near-infrared spectroscopy (NIRS) has been developed as a promising non-invasive and real-time technique to quantify tumor vascular oxygenation[1,2]. MRI can provide quantitative pO_2 using Fluorocarbon Relaxometry using Echo planar imaging for Dynamic Oxygen Mapping (FREDOM)[3]. This provides pO_2 at multiple specific locations simultaneously with millimeter spatial resolution. It is of interest to correlate NIRS and FREDOM in order to investigate tumor physiology and pathology under therapeutic interventions[4]. Since NIRS is based on fiber-optic technology, it should be compatible with MRI and we now demonstrate simultaneous measurements.

Mathods and Materials: Ten rats were implanted with 13762NF breast adenocarcinomas in surgically prepared foreback pedicles. A Hemholtz coil with a diameter of 3cm was designed to facilitate simultaneous MRI and NIRS measurements. We measured tumor oxygenation parameters simultaneously by FREDOM and NIRS during respiratory challenge with oxygen or carbogen. Response was characterized in terms of both magnitude and rate of oxygenation.



Figures: *Simultaneously measured changes with respiratory challenge in* ***(a)*** *mean pO_2 by MRI and* ***(b)*** *ΔsO_2 by NIR.. Correlations in* ***(c)*** *pO_2 response rate vs A_1/τ_1 in ΔHbO_2 and* ***(d)*** *pO_2 vs f_1/f_2 in nine tumors. Oxygen intervention (solid point) or carbogen intervention (open point). A_1 and τ_1 are the maximum amplitude and time constant, respectively, for the growth of $[HbO_2]$ in well perfused region of tumor. f_1 and f_2 are the blood perfusion rates in well and poorly perfused regions of tumor, respectively*[2].

Results: Each tumor showed a rapid response to challenge with hyperoxic gas with a significant increase in $[HbO_2]$. pO_2 increased significantly, but more slowly. The changes can be characterized in terms of magnitude of response and kinetics. In every case there was a rapid response characterized by τ_1, which was sometimes followed by a second component. There was a strong correlation between the rate of tissue response (pO_2) and the fast component (A_1/τ_1) which represents perfusion. This is consistent with greatest response for the most perfused tumors. We also find a correlation between HbO_2 perfusion rate ratio (f_1/f_2) and maximum pO_2 observed with hyperoxic gas. However the correlation was predicated on selecting only those voxels which showed increased pO_2 of more than 10 torr in hyperoxic intervention.

Discussion:

These studies demonstrate the feasibility of conducting simultaneous NIRS and MRI oximetry. We believe the correlation of vascular oxygenation (oxygen delivery) and tissue pO_2 can provide valuable insights into tumor patho-physiology and response to intervention.

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