Sodium (^{23}Na) MR Imaging in Pediatric Astrocytomas

Vincent Kyu Lee[1], Rafael Ceschin[1], Yongxian Qian[2,3], Fernando Boada[4], James Mountz[5], Regina Jakacki[6], Ian Pollack[7], and Ashok Panigrahy[2]
[1]*Radiology, University of Pittsburgh, Pittsburgh, Pa, United States,* [2]*Radiology, University of Pittsburgh, Pa, United States,* [3]*Bioengineering, University of Pittsburgh, Pa, United States,* [4]*Radiology, New York University, NY, United States,* [5]*University of Pittsburgh, Pa, United States,* [6]*Pediatrics, University of Pittsburgh, Pa, United States,* [7]*Pediatric Neurosurgery, University of Pittsburgh, Pa, United States*

INTRODUCTION:

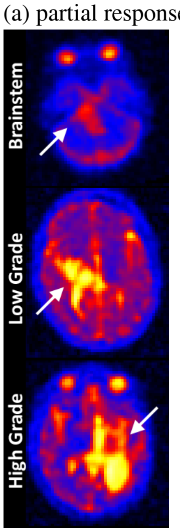
Sodium (^{23}Na) MR is known to be a biomarker of proliferation in animal models[1]. ^{23}Na-MR imaging has been used to noninvasively quantify total tissue sodium concentration in adult brain tumors[2]. However, the utility of ^{23}Na MR for evaluating tumor proliferation in pediatric brain tumors is unknown. In this study, we used ^{23}Na MR imaging to characterize sodium intensity values in pediatric gliomas with different grades and biology. We tested the hypothesis that: (1) ^{23}Na MR in pediatric astrocytomas would differ from adjacent normal pediatric brain tissue; and (2) ^{23}Na MR measurements would distinguish different types of pediatric astrocytoma at various points of therapy.

METHODS:

A total of 26 pediatric astrocytoma patients (brainstem gliomas (n=10), low grade (n=6) and high grade (n=10) supratentorial gliomas ; median age=11 years) at different points of therapy were prospectively recruited and scanned with a 3T TIM Trio (Siemens AG, Erlangen, Germany) using a dual-tuned, dual-quatrature (^{1}H-^{23}Na) volume head coil (Advanced Imaging Research, Cleveland, OH, USA), and twisted projection imaging with the following sequence[3] parameters: FOV=220mm, voxel size=3.44mm (isotropic), matrix size=64x64x64, TR=100ms, TE=0.44ms. A total of 8 patients had serial examinations (total of 38 exams). Sodium intensity was determined in normal appearing grey matter (GM), white matter (WM), CSF (cerebral spinal fluid), and the vitreous humor in all of the patients. In addition, ^{23}Na intensity was calculated in tumors and determined from ^{23}Na signal intensities measurements that either demonstrates (1) contrast enhancement and/or (2) non-enhancing FLAIR hyperintensities. Manually drawn ROIs were used to measure average tissue intensities from normalized images.

RESULTS:

^{23}NA MR images of different tumor types and sodium signal intensity averages (along with normal healthy brains regions) are presented in Figures 1 and 2. The sodium averages of CSF(126.64±11.32), Vitreous(99.83±14.90), GM(58.93±5.70) and WM(52.49±4.72) were distinct and significantly different from each other (≥1 standard deviation apart). A negative association between age and GM (-0.85857; R=0.53207; p-value=0.0036), and age and WM (-0.78723; R=0.50744; p-value=0.0058) was observed. Of the tumors, brainstem glioma showed consistently low signal intensity overall at (50.60 ±9.42), and low grade supratentorial astrocytomas demonstrated relatively high intensity (84.51±10.36). The high grade astrocytoma (72.42±10.01) also showed high intensity relative to GM. However, across all tumors, lesions categorized as high grade had larger variance (±23.5 standard error from the mean). Of the eight serial cases, three cases demonstrated changes in sodium intensities that were related to (a) partial response to immunotherapy (Figure 3); (b) development of treatment related necrosis; and (c) tumor progression.



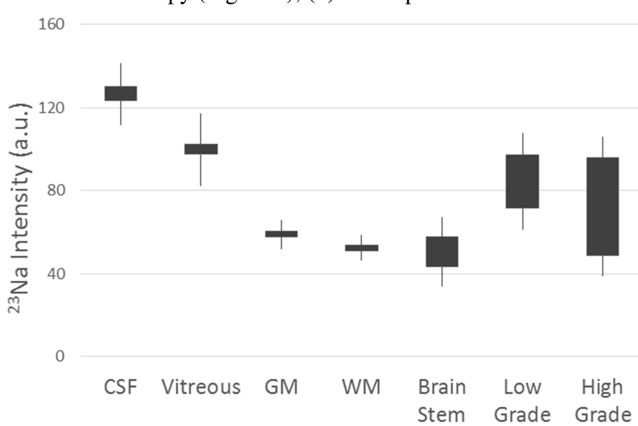


Figure 1. (*left*) ^{23}Na MR of Brain Stem (top), Low Grade (middle) and High Grade (bottom) gliomas.

Figure 2. (*above*) ^{23}Na Averages in Pediatric Brains.

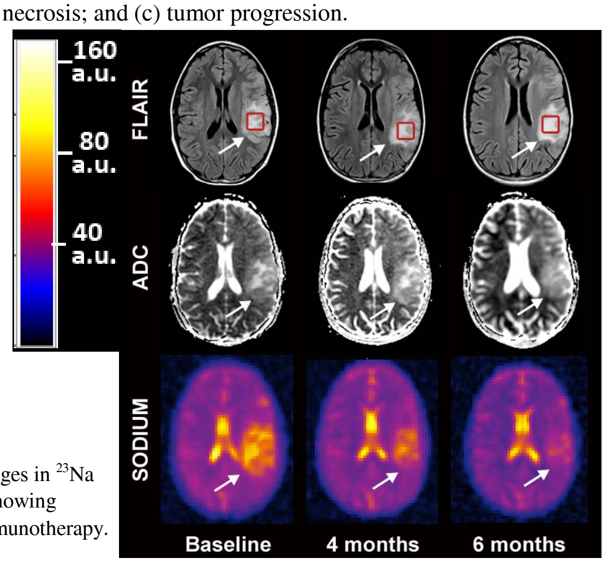


Figure 3. (*right*) Changes in ^{23}Na intensities in patient showing partial response to immunotherapy.

DISCUSSION:

^{23}Na MR imaging can be used to distinguish sodium intensities (and sodium concentrations with application of proper calibration) in pediatric astrocytomas relative to adjacent normal tissue. Brainstem gliomas, which have a poor prognosis, were characterized by decreased sodium intensity relative to supratentorial low and high grade glioma. Total sodium did not distinguish between low and high grade supratentorial lesions. However, we noted that the high grade supratentorial glioma demonstrated significant variability in signal intensity which may be explained by spatial and temporal heterogeneous tumor response in the setting of ongoing therapy. Our preliminary serial results suggested that sodium imaging may be useful to monitor these spatial and temporal heterogeneous treatment responses in pediatric patients undergoing innovative targeted therapies. Controlling for these necrotic and proliferative zones by a voxel based analysis, or methods distinguishing intracellular from extracellular sodium signal may offer improved characterization of sodium intensity in high grade tumors.

REFERENCE: [1] Schepkin, V.D., et al. MRI 2006; 24.3: 273-278. [2] Ouwerkerk R., et al. Radiology 2003; 227.2: 529-537. [3] Boada F.E., et al. MRM 1997; 37:706-715.