Incorporation of MR Spectroscopic Imaging into Gamma Knife Radiosurgery Treatment Planning

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INTRODUCTION:

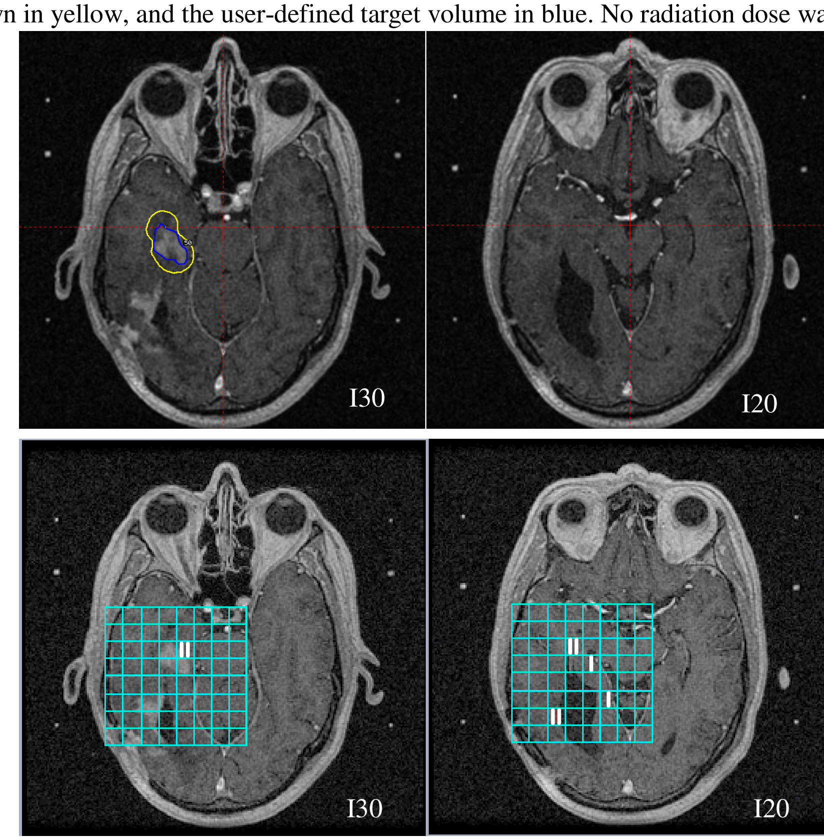
The Gamma Knife is a radiosurgical device used to treat a variety of brain lesions with an array of 201 converging, collimated Co-60 gamma radiation beams focused on a single point. Infiltrative gliomas are known to extend beyond the area of contrast enhancement, however, conventional Gamma Knife treatment planning typically involves identifying the radiosurgical target volume on contrast-enhanced T_1-weighted MR images. MR spectroscopic imaging has been used to identify in the adjacent tissue biochemical changes suggestive of malignancy, opening the possibility of extending the radiosurgical treatment volume to include these regions (1). We present further work in this area confirming the utility of MRSI in Gamma Knife treatment planning, as observed in patient MRSI datasets showing spectra from MRSI voxels (outside of and adjacent to the planned radiosurgical target volume) with abnormal choline to NAA ratios as compared to age and brain region-matched controls.

METHODS;

All scans were performed on a General Electric 1.5T Signa MR scanner equipped with "Echospeed" gradients and a standard quadrature head coil. The PRESS pulse sequence was used to acquire 3D MRSI datasets with the following paramenters: TE=144ms, TR=1000ms, 8x8x8 phase encodes with an 8x8x8 cm FOV for patients and 16x12x8 phase encodes for a 16x12x8 cm FOV for normal controls due to the larger excitation volume. Over-excitation of the excitation voxel by a factor of 1.3 was used in conjunction with high-bandwidth spatial-saturation pulses placed around the excitation voxel to minimize the effect of imperfect slice profiles and chemical shift displacement. To meet time constraints, the FOV was chosen to be small enough to minimize the number of phase encodes, but large enough relative to the dimensions of the excitation voxel to reduce phase wrap artifacts. Spectral analysis with SAGE (General Electric) and "LCModel" provided metabolite ratios for the age- and brain-region-matched normal controls used to define thresholds for malignancy (Cho:NAA ratios of two standard deviations or greater from normal).

RESULTS:

Whole brain 3D MRSI datasets were acquired from normal controls in the age ranges of 20-39 years, 40-59 years and 60 – 79 years with n=10 per age group to set the threshold Cho/NAA ratio for abnormal spectra in the Gamma Knife patient datasets (n=5). The mean and standard deviation of the Cho/NAA ratio were calculated for a number of brain regions for each age group. A representative patient dataset is shown in the figure. The Gamma Knife treatment plan is shown on the top row for two different slices separated by 10 mm. On the top left, the 50% isodose curve is shown in yellow, and the user-defined target volume in blue. No radiation dose was planned for tissue at slice position I20 mm, as seen on the top right image. The MRSI data are shown on the bottom row for the same two slices. Several voxels were identified in the spectral analysis as having Cho/NAA ratios deviating by more than two standard deviations from normal control values (marked with a single white bar) or three standard deviations (marked with a double white bar). None of this tissue was targeted for radiation.



DISCUSSION AND CONCLUSION:

Based on the contrast-enhanced MRI, the radiosurgical target volume does not always include the tissue marked as abnormal according to the Cho/NAA ratio as seen in the MRSI dataset ("abnormal" is defined as at least two standard deviations greater than normal control levels for the same brain region and age range). Often these MRSI –abnormal voxels are adjacent to the targeted radiosurgical volume and could easily be included by slight expansion of the target volume boundary, provided these areas do not correspond to eloquent cortices. The impact of such treatment modifications could be assessed in a future survival study given the short life expectancy of these patients.

References:

1. Chan AA et al, J Neurosurg,101(3):467-75, 2004.