Brain Tumor Nosologic Maps Obtained from T2-Weighted Images

M. Martín-Landrove[1,2]

[1]Centro de Física Molecular y Médica, Facultad de Ciencias, Universidad Central de Venezuela, Caracas, Venezuela, [2]Fundación Instituto de Estudios Avanzados, IDEA, Caracas, Venezuela

INTRODUCTION

Tissue classification is a necessary step to obtain the spatial distribution of pathology, i.e., a nosologic map, and typically it is performed by the combination of different medical image modalities, sometimes including invasive histopathological studies. Different MRI techniques usually exhibit different spatial resolutions and as a consequence a partial volume problem is always present affecting considerably the precise determination of nosologic maps, i.e., in the case of T2-weighted or diffusion-weighted images, voxel intensity decays multiexponentially. Present work discusses different approaches to overcome the partial volume problem on T2-weighted images, by analysis of transversal relaxation rate distributions.

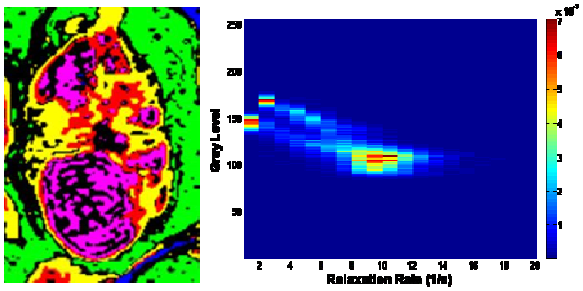

Figure 1. On the right, correlation between gray level and relaxation rate for a tumoral lesion. Left, colored nosologic map, red and yellow indicate tumor and edematized tissue respectively, green unaffected tissue, blue cerebrospinal fluid and violet, necrosis.

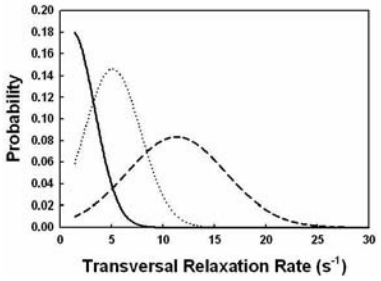

Figure 2. Tissue probability distributions: dashed line, unaffected tissue, dotted line, tumoral tissue and continuous line, cerebrospinal fluid or necrosis

MATERIALS AND METHODS

The simplest approach to perform tissue classification based solely on relaxation data, called from now on as method 0, is to establish a correlation between gray levels and estimated relaxation rates in T2- weighted images, as shown in Figure 1. In this case, unless supported by in vivo spectroscopy data, tissue classification depends strongly on user knowledge of the tumoral lesion and organ anatomy. Less user dependent schemes relay on the detailed comparison of relaxation rate distributions over the lesion and over healthy or unaffected tissue. For this comparison to be effective, so called Inverse Laplace Transform (ILT) algorithms [1,2] have to be used and tissue probability functions can be obtained, as shown in Figure 2.

In general, ILT algorithms are time consuming so the initial exploration can not be applied on a pixel by pixel basis but has to be limited to extended regions including several or many pixels. The capacity of the ILT algorithm to resolve different relaxation rates, i.e., different kinds of tissue, is of key importance for the precise tissue probability determination.

Three methods can be proposed to obtained nosologic maps:

Method 1: Based on the tissue probability functions, mean relaxation rates are determined. Image intensity decay is assumed to be a linear combination of exponential decaying functions. The coefficients are determined by linear regression analysis and represent the proportion on which each tissue is present.

$$I(\alpha) = bl + \sum_i A_i X_i(\alpha) \qquad X_i(\alpha) = \exp\left(-\langle\rho\rangle_i \alpha\right)$$

Method 2: The image intensity decay is modeled by a single exponential plus a baseline correction and the relaxation rate value is obtained by nonlinear regression analysis. To determine the proportion on which each tissue is present in the pixel, tissue probabilities are evaluated for that particular relaxation rate value.

$$I(\alpha) = bl + C\exp(-\alpha\tilde{\rho}) \qquad \tilde{p}_i(\tilde{\rho}) = \exp\left(-\left(\tilde{\rho} - \langle\rho\rangle_i\right)^2 / 2\sigma_i^2\right) / \sigma_i\sqrt{2\pi}$$

Method 3: Direct application of the ILT algorithm on sub regions over the lesion. The number and extension of sub regions is based on image homogeneity, texture or any other image parameter in order to optimize the computational time. The output of the ILT algorithm, i.e., relaxation rate distribution function is projected on the tissue probabilities to determine the proportion on which each tissue is present in the pixel.

$$I(\alpha) = \int_0^\infty d\rho\, e^{-\alpha\rho} P(\rho) \qquad p_i(\rho) = \exp\left(-\left(\rho - \langle\rho\rangle_i\right)^2 / 2\sigma_i^2\right) / \sigma_i\sqrt{2\pi} \qquad \tilde{p}_i = \int_{\rho_{\min}}^{\rho_{\max}} p_i(\rho) P(\rho) d\rho$$

RESULTS AND DISCUSSION

Results are shown in Figures 1 and 3. Figure 3a shows the result of the application of method 1. The classification of the tissue depends on the value of the correlation coefficient squared, 0.99 for this case. Figure 3b was obtained with method 2 appliying Levenberg-Marquardt algorithm for nonlinear regression analysis and Figure 3c represents the fusion of tissue probabilities after the application of method 3 over ROI´s given by n x n pixels, with n = 3 to 11. Among the different methods, method 1 is faster and can be used as a method for total image inspection prior to more detailed analysis, particularly in tumor boundary. Method 2, next in computation time, due to the overlap in the tissue probability distributions is responsible for the appearance of tumor positive voxels, particularly in tissue interfaces. Method 3 represents a more refined method to obtain the nosologic map. Unfortunately, the precision of ILTA to determine the actual distribution of the parameter depends on a high number of initial conditions and as consequence its use is limited to few voxels, unless a parallel code could be implemented.

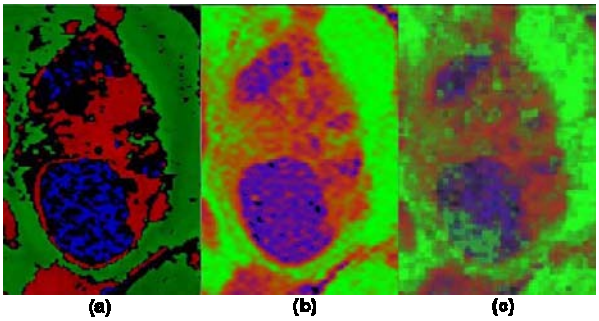

Figure 3. Application of the methods to obtain nosologic maps over the same region: (a) method 1, (b) method 2 and (c) method 3.

CONCLUSIONS

Nosologic maps of tumoral lesions can be obtained using T2-weighted images. Analysis of image data by an inversion algorithm (Inverse Laplace Transform) allows for tissue classification and contributes to solve the partial volume problem.

REFERENCES

[1] R. Martín and M. Martín-Landrove, “A novel algorithm for tumor characterization by analysis of transversal relaxation rate distributions in MRI”, in *Spatially Resolved Magnetic Resonance*, Blümler, P., Blümich, B., Botto, R., Fukushima, E., eds., chap. 11, pp. 133-138, Wiley-VCH, 1998

[2] M. Martín-Landrove, F. Mayobre, I. Bautista and R. Villalta, “Brain tumor evaluation and segmentation by in vivo proton spectroscopy and relaxometry”, *MAGMA*, 18:316-331, 2005