Relationships among ISODATA, DWI, MTT, and T2 Lesions in Stroke

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Synopsis

Eleven patients underwent our magnetic resonance imaging (MRI) stroke protocol conducted at acute, subacute, and chronic times, consisting of T1-(T1WI), proton-density-(PDWI), T2- (T2WI), diffusion- (DWI), and bolus tracking perfusion-weighted images (PWI). All images were co-registered and warped to the acute T2WI before analysis. Multi-parametric ISODATA, ADC, T2, and mean transit time (MTT) maps were created for each time point, and mean values and lesion sizes were estimated. Acute ISODATA lesion correlated well with acute DWI and MTT lesions. In some patients, acute MTT lesion over-estimated final lesion. Chronic ISODATA lesion correlated well with chronic T2 lesion and NIH stroke scale.

Introduction

After stroke, brain tissue undergoes time dependent heterogeneous histopathological changes. These tissue alterations have MRI characteristics, which allow segmentation of ischemic from non-ischemic tissue. MRI segmentation usually generates different zones within the lesion that may reflect heterogeneity of tissue damage. We have developed an objective (unsupervised) computer segmentation algorithm implementing an Iterative Self-Organizing Data Analysis Technique (ISODATA) for MRI segmentation and tissue characterization [1],[2]. This method identifies clusters in the feature space and partitions the brain image into normal and abnormal tissue regions using multi-parametric MRI (1PDWI, 1T2WI, 1T1WI, 2DWI). The contrasts of these images are functions of tissue proton density, relaxation times, and diffusion, which are influenced by abnormalities such as ischemia. DWI shows ischemic regions within minutes to hours after stroke onset. On the other hand, MTT map for the passage of the bolus through the brain using PWI shows the regions with abnormal blood perfusion immediately after stroke onset. It is hypothesized that MTT abnormalities correspond to tissues at risk while DWI abnormalities evolve into infarction. Although in most cases these two abnormalities coincide, in some patients they are different. This is referred to as diffusion-perfusion mismatch. The purpose of this work was to study the relationship among ISODATA, DWI, MTT, and T2WI lesions and National Institute of Health Stroke Scale (NIHSS) in stroke patients including those with diffusion-perfusion mismatch.

Methods

Eleven patients underwent our stroke protocol conducted at acute (0-12 h), subacute (72-168 h), and chronic time points (≥ 3 months), consisting of sagittal T1, axial multiple spin-echo T2WI, pre-and post-gadolinium T1WI, DWI, and bolus tracking PWI. All MRI studies were performed on a GE 1.5 T system. The MRI protocol took approximately 35 minutes to complete, and its parameters were as follow: T1 localizer (TR/TE =600/14 ms), axial T2WI (TR/TE = 2800/30, 60, 90, 120 ms, FOV = 23×23 cm, matrix = 256×192, slice thickness 6 mm) and axial DWI (TR/TE=10,000/101 ms, b-value=1000, 600, 300, and 0 s/mm^2, FOV 23×23, matrix = 128×128, slice thickness 6 mm, 1 NEX on three orthogonal axis). All MR images were coregistered and warped to the acute T2WI [3]. Multi-parametric ISODATA, MTT, ADC, and T2 maps were created for each time point using Eigentool [4]-[6]. Segmented ISODATA clusters were standardized based on their relative Euclidean distances from the normal tissue and CSF in the multi-parametric MRI feature space to generate a color-coded image representative of the tissue damage [2]. Mean values and lesion sizes were measured on the ISODATA segmentation results, DWI (b=1000), T2WI, MTT, ADC, and T2 maps at each time point for each patient. Acute and chronic ISODATA lesions were compared to acute DWI, acute MTT, and chronic T2WI lesions to investigate their correlations with the current standards utilized in the clinical setting. Also, correlations of ISODATA results with clinical outcomes as defined by NIHSS were found.

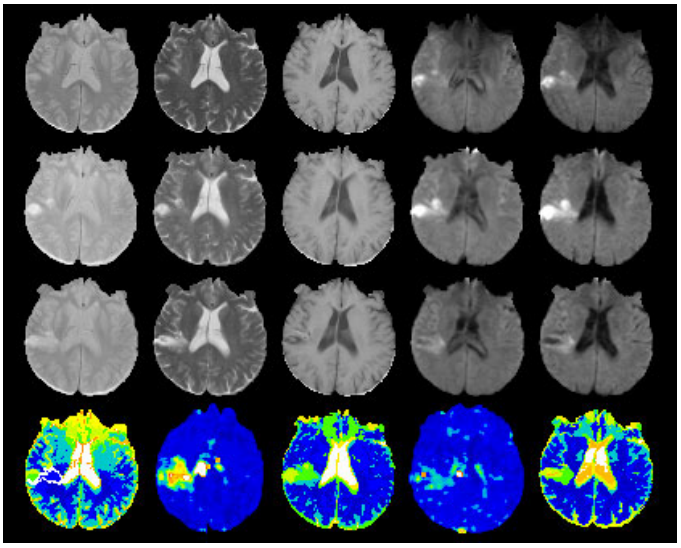

Fig.1. First to third rows (from left to right) show proton density-, T2-, T1-, and diffusion-weighted (b=600,1000) images of a stroke patient at acute, subacute, and chronic times, respectively. Fourth row (from left to right) shows ISODATA and MTT maps at acute and subacute times and ISODATA map at the chronic time, respectively. The border of the tissue at risk is marked in white on the acute ISODATA. This zone along with the other lesion zone (on its left side) defines the final ischemic lesion (as seen on the chronic T2WI in the 2nd image on the 3rd row).

Results

In all studies, ISODATA found multiple zones for the ischemic lesion at all time points (acute, subacute, chronic). Overall, the total ISODATA lesion at the acute time was correlated well with acute DWI and MTT lesions and moderately with the chronic T2WI lesion. The moderate correlation is attributed to growth or reduction of ischemic lesions over time. In some patients, acute MTT lesion over-estimated the chronic T2WI lesion. Chronic ISODATA lesion correlated well with chronic T2WI lesion and NIH stroke scale and moderately with acute DWI and MTT lesions, again due to temporal evolution of ischemic lesions. Details are listed in Table 1. Sample images and maps from a case with diffusion-perfusion mismatch are shown in Fig. 1. Note that the total ISODATA lesion enlarged from acute to sub-acute returning to the initial size at the chronic time matching T2 lesion. Also, note that the perfusion lesion at the acute time over-estimated the final lesion (chronic T2WI lesion).

Table 1. Correlation coefficients and p-values (in parenthesis) for the lesion sizes.

ISODATA	Acute DWI	Acute MTT	Chronic T2WI	Corresponding NIHSS
Acute	0.87 (<0.01)	0.97 (<0.01)	0.56 (0.06)	0.22 (0.35)
Chronic	0.77 (<0.01)	0.58 (0.01)	0.97 (<0.01)	0.97 (<0.01)

Conclusion

We have demonstrated that analysis of conventional multi-parametric MRI data (PDWI, T2WI, T1WI, DWI) by our ISODATA method segments the ischemic tissue from normal tissue and characterizes the tissue damage. Acute and chronic ISODATA lesions correlate well with acute DWI and MTT lesions and with chronic T2WI lesion, respectively. The method may predict the final lesion without using PWI. In addition, it may predict the final lesion better than MTT or DWI when there is a diffusion-perfusion mismatch.

References

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