Automatic Arterial Input Function Measurement for Perfusion MRI

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Introduction

Quantitative perfusion MRI using dynamic susceptibility contrast requires estimation of arterial input function (AIF) (1). Typically, this involves manually selecting a region-of-interest (ROI) surrounding middle cerebral artery (MCA) (2). Rempp, et al (3) and Murase, et al (4) proposed two methods for computer-assisted identification of the pixels for AIF measurement. Both methods, however, require user identification of an ROI surrounding the MCA. An extension of the original approach by Rempp (3) could include pixels scattering across the whole imaging volume, instead of only pixels surrounding the MCA, for the measurement of AIF. The purpose of this work was to develop a completely automatic algorithm for identifying an optimal cluster of pixels surrounding the MCA in order to streamline the estimation of AIF. Based on tracer kinetics, we proposed that the optimal cluster of pixels for AIF would have the following characteristics: 1) high cerebral blood volume; 2) high peak of R2 change as a ramification of high contrast agent concentration; and 3) early time-to-peak.

Materials and Method

All MRI experiments were carried out on a standard 1.5T clinical MRI system using a circularly polarized head coil (Magnetom Vision, Siemens Medical Systems, Erlangen, Germany). Seven normal (37.14±9.84 years of age), four brain tumor patients (42.25±19.00 years) and five ischemic stroke patients (61.60±13.96 years) were enrolled. The perfusion scan used a single-shot spin-echo echo-planar imaging sequence (TR/TE = 3 s/60 ms) covering seven 6-mm 2D oblique-axial slices with the lowest slice containing the MCA. The sequence was repeated 60 times continuously, with intravenous bolus injection of Gd-DTPA (5 ml in 1 second) being administered at 7th scan.

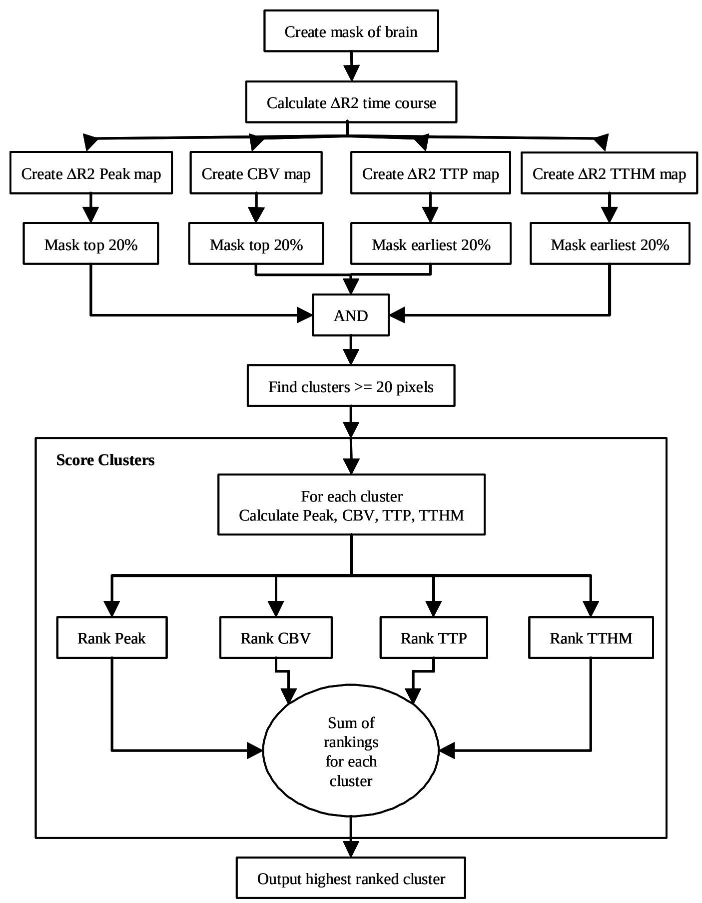

Figure is the flowchart of the algorithm. The first step of data processing was calculating the time-course of ΔR2 maps inside the brain: $\Delta R2_i = -\ln (S_i/S_0) / TE$ where S_0 is the baseline signal derived from averaging pre-injection time points, S_i is *i*th time point signal, and TE = 60 ms. Using the time series of ΔR2 maps, four maps were generated: 1) ΔR2 peak map ("Peak"); 2) cerebral-blood-volume (CBV) map in which each pixel value is the area underneath the ΔR2 time-course; 3) ΔR2 time-to-peak (TTP) map; and 4) ΔR2 time-to-half-maximum (TTHM) map. Slice acquisition order was taken into account in the calculation of TTP and TTHM maps. For the Peak and CBV maps, pixels with the highest 20% values were masked. For the TTP and TTHM maps, pixels with the smallest values were masked. In the next step, the logical AND map of the four masked maps was generated. From the AND map, the algorithm searched for clusters of more than 20 pixels, and calculated the ranks of each cluster for the four criteria (i.e., Peak, CBV, TTP, TTHM). For TTP and TTHM, two values are considered essentially the same if $|t_i - t_j| < 1/2$ TR. The final step was to calculate the sum of the ranks for each cluster, and the highest ranked cluster was chosen as the optimal cluster for the measurement of AIF.

Results and Conclusion

For all the normal subjects, the optimal cluster (i.e., the cluster with the highest ranking) was either along the left or the right MCA. The program also correctly identified the MCA in all the four brain tumor patients. In the stroke patient, the algorithm was run in either the left or the right hemisphere depending on the infarct lesion location in order to take into account the presumably delayed perfusion in the lesion hemisphere (2). In four of the five stroke patients, the optimal clustered, or the highest ranked cluster, were found to be along MCA. The program didn't identify any cluster at all in one stroke patient. Examining the raw images revealed that the time course data didn't show the characteristic signal drop-recovery expected to see with the passage of contrast agent, suggesting the contrast agent inject was a faulty one.

In addition to the optimal cluster, other clusters were found to be along other arteries such as ICA. It should be emphasized that the use of 20% as the threshold for generating masks was empirical, and could be adjusted. In each of the subject except for the faulty stroke patient scan, excellent perfusion images (i.e., CBF, MTT) were obtained using the measured AIF. These results demonstrated the effectiveness of the algorithm.

Acknowlegement

This work was supported in part by a research grant from the Whitaker Foundation (RG-00-0231)

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