

Hemodynamic segmentation of MR brain perfusion images using Independent Component Analysis, Thresholding, and Bayesian Estimation (ICA-TBE) techniques

Y. H. Kao¹, W. Y. Guo², Y. T. Wu¹, K. C. Liu¹, W. Y. Chai¹, C. Y. Lin¹, Y. S. Hwang¹, J. K. Liou², H. M. Wu², H. C. Cheng², T. C. Yeh², J. C. Hsieh²,
M. H. Teng²

¹National Yang-Ming University, Pei-Tou, Taipei, Taiwan, ²Taipei Veteran General Hospital, Pei-Tou, Taipei, Taiwan

Synopsis Dynamic-susceptibility-contrast perfusion imaging is a widely used imaging tool for *in vivo* study of cerebral blood perfusion. However, visualization of different hemodynamic compartments is less investigated. We use independent component analysis, thresholding, and Bayesian estimation to concurrently segment different tissues on perfusion images of normal volunteers. Based on the spatio-temporal hemodynamics, sequential passages and microcirculation of contrast-agent particles in brain tissues are decomposed and analyzed. Late and multi-phasic perfusion, indicating the presence of contrast agents, is observed in choroid plexus and CSF areas. An arterial input function is modeled from an arterial area on the same slice.

Materials and Methods Perfusion brain images (1) of five healthy volunteers were acquired on a 1.5-Tesla clinical scanner. A gradient-echo, echo-planar-imaging pulse sequence was used. Scan parameters were: TE/TR = 60/1000 ms, flip angle = 90 degree, field of view = 24 cm × 24 cm, image matrix = 128×128, slice thickness = 5 mm, gap = 5 mm, three slices, and one average. Twenty ml of Gd-DTPA followed by 20 ml of normal saline were administrated through an antecubital vein at a flow rate of 3 ml/sec using a power injector. Tissues with different blood supply patterns were assumed to be distributed in a spatially independent manner on the perfusion images, so that they could be distinguished by ICA. The FastICA technique (2) was used to process perfusion images. We found the output independent-component images provided a coarse segmentation of the perfusion images. To refine segmentation results, we utilized thresholding and Bayesian estimation on the perfusion and independent-component images.

Results Figure 1 illustrates the application of FastICA on perfusion images with five output independent-component images. The calculated signal-time curves plotted in (a) were rescaled to demonstrate the sequential passages of contrast agents at different tissues. Each independent-component image consisted of two or three tissue types. The major tissue types were choroid plexus (CP) (b), artery (c), vein and sinus (VS) (d), gray matter (e), and white matter (f). Figure 2(a) displays the final segmentation result in a color-coded composite image, generated using the Bayesian estimation. The overestimates of artery and VS areas were caused by magnetic susceptibility effect. Figure 2(b) plots the measured signal-time curves for these segmented areas. The concentration-time curve of the artery region was modeled as an arterial input function. To illustrate the sequential passages of contrast agents, the concentration-time curves were rescaled to their maximum values as illustrated in Fig. 2(c). The rescaled curves demonstrate that the bolus of contrast agents arrived at the artery first, followed by gray matter, white matter, and VS. Good recirculation in these tissues was observed, indicating that their blood brain barriers were all well intact. However, CP and CSF have different curve patterns because of their different microcirculations.

Discussion Our method has several advantages: 1) the concurrent and systematic segmentation of tissues with different hemodynamic patterns; 2) the delineation of sequential passage and microcirculation of contrast agent to these tissues; and 3) the effective modeling of an arterial input function on the same slice location for relative CBF calculations. The resultant information on tissue characteristics and hemodynamics will further expand our knowledge of cerebral blood circulation in human brains.

References:

1. Rosen BR, Belliveau JW, Vevea JM, Brady TJ. Magnetic Resonance in Medicine 1990;14:249-265.
2. Hyvarinen A, Karhunen J, Oja E. Independent Component Analysis, John Wiley & Sons, Inc., New York, 2001.

