# Independent component analysis for assessing tissue at risk of infarction in acute ischemic stroke

Venkata Veerendranadh Chebrolu[1], Ashish Rao[2], Dattesh D Shanbhag[1], Sandeep N Gupta[3], Uday Patil[1,4], Patrice Hervo[5], Catherine Oppenheim[6,7], and Rakesh Mullick[8]
[1]*Medical Image Analysis Lab, GE Global Research, Bangalore, Karnataka, India,* [2]*Bio-Medical Signal Analysis Lab, GE Global Research, Bangalore, Karnataka, India,* [3]*Biomedical Image Processing Lab, GE Global Research, Niskayuna, NY, United States,* [4]*Manipal Health Enterprises Pvt. Ltd., Bangalore, Karnataka, India,* [5]*GE Healthcare, Buc, France,* [6]*Departments of Radiology and Neurology, Centre Hospitalier, Sainte-Anne, Paris, France,* [7]*Université Paris Descartes, Paris, France,* [8]*Diagnostics and Biomedical Technologies, GE Global Research, Bangalore, Karnataka, India*

**Target Audience:** Physicists and radiologists interested in acute ischemic stroke.

**Purpose**: In acute ischemic stroke (AIS), dynamic susceptibility contrast (DSC) weighted MRI has been used for clinical assessment of brain tissue that can be salvaged using reperfusion therapies. Perfusion characteristics of brain tissue have typically been studied by parameterizing the perfusion signal time-course in terms of mean-transit-time (MTT) and the time at which the deconvolved residue function maximizes (Tmax). Quantitative parametric maps may require user inputs for arterial input function (AIF) and the results may vary depending on the choice of AIF. A non-parametric approach for identifying stroke core and hypo-perfusion regions without the need of AIF may be desirable in AIS setting. Independent component analysis (ICA) is a blind source separation technique that may separate spatially independent regions in a mixture data and can be potentially utilized for differentiation of the degree of perfusion in AIS. Previously, multi *b*-value diffusion-weighted imaging (DWI) data was analyzed using ICA for extracting perfusion information from diffusion data [1]. ICA on DSC data was used to distinguish perfusion kinetics of brain tumors from normal tissue [2]. In this work, we demonstrate the use of ICA on DSC data for identifying hypo-perfused regions and compare the results with Tmax and DWI based analysis of AIS.

**Methods**: *Imaging:* Ten AIS patients in the anterior circulation (Sainte-Anne Stroke unit, Paris) were scanned using DWI and DSC-MRI within 4.5 hours of onset on a 1.5T GE Signa HDx clinical scanner using an 8-channel head coil. (a) *DWI Imaging:* Axial DWI trace images were acquired using a SE-EPI sequence, TE=67–100 ms, TR=4.5–7s, FA=90°, NEX=2, 256×256 matrix, FOV = 240×240 $mm^2$, slice thickness = 3.5-7 mm, b = 0 $s/mm^2$ and 1000 $s/mm^2$. (b) *DSC-MR Imaging:* Axial oblique slices were acquired using a GE-EPI sequence, TE = 19–60 ms, TR = 2000 ms, FA = 90°, number of phase measurements = 25 (2 s/phase), slice thickness = 5–7mm, Matrix: 64×64 to128×128, FOV = 240×240 $mm^2$. Appropriate IRB approval was obtained. *Map Generation*: The DWI and DSC-MRI images were processed using READY View tool within the Advantage Workstation platform (GE Healthcare, Buc, France) to generate apparent diffusion coefficient (ADC) and Tmax maps. *ICA:* We hypothesized the following five sources for DSC data in AIS brain: normal brain tissue, hypo-perfused brain tissue, cerebral spinal fluid (CSF), motion and noise. The first two time-points in the DSC data were removed before ICA to avoid saturation artifacts. JADE-ICA [3, 4] was applied to DSC intensity time-course data to obtain five spatially independent components (ICs). Each IC comprised of a time course and a 3D spatial distribution map. Motion and noise components were identified and removed. The remaining three components were retained for further analysis. 3D spatial map of each IC was converted to a spatial z-score as follows :( Voxel value − Mean of spatial map) / (Standard deviation of spatial map). A z-score greater than 3 is considered as statistically significant. The time courses for each IC were normalized by their own first value to obtain relative intensities.

**Results and Discussion**: Fig 1 shows ICA analysis in three representative cases. The Tmax and ADC maps are also shown for comparison. The time-course of each component was interpreted as follows: ***Component #1*** has the least percentage change in the contrast over time. CSF and infarcted regions have high z-scores (> 3) in component#1. Regions with low ADC (less than $0.6\times10^{-3}$ $mm^2/s$) and high Tmax (greater than 10s) may be considered as infarcted regions. ***Component #2*** has the earliest contrast arrival and shortest time-to-minimum. Regions with normal perfusion have high z-scores in component #2. ***Component #3*** has the longest time-to-minimum. Regions at risk of infarction have high z-scores in component #3. Regions with normal ADC (greater than $0.6\times10^{-3}$ $mm^2/s$) and elevated Tmax (greater than 6s) may be considered as tissues at risk of infarction. ICA maps allows for evaluating the relative contributions of different components (indicating different levels of perfusion) at a given voxel. Relatively, the Tmax provides only a single value which may be affected by partial volume effects, errors in AIF and the AIF location (whether ipsilateral or contralateral to stroke region). The ICA method generates components without the need of AIF. This may allow estimation of hypo-perfusion in regions not clearly indicated on Tmax maps (Tmax < 6s). Overall, the results indicate good correspondence between ICA results and AIS evaluation based on Tmax and ADC maps.

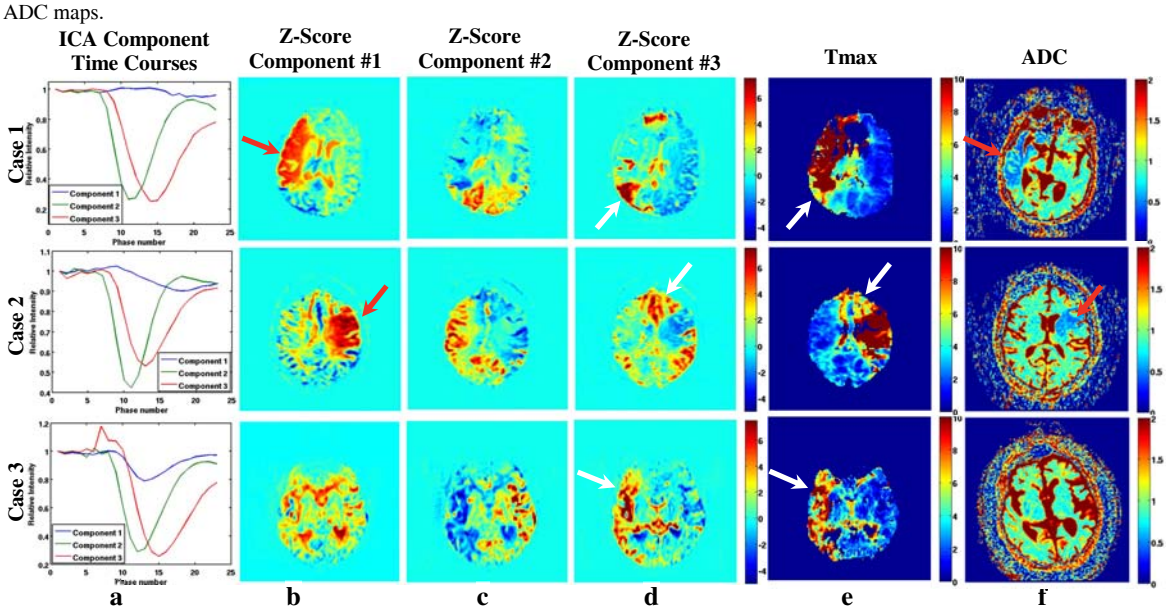


***Figure 1:*** *ICA component time courses (a) and z-scores (b-d) for 3D spatial distribution maps of components* 1, 2 *and* 3 *respectively. Component* 1 *has least percentage change in DSC signal, component* 2 *has the earliest bolus arrival and time-to-minimum and component* 3 *has the longest time to minimum. (e) Tmax (seconds) (f) ADC* × 1000 *($mm^2 s^{-1}$). Core ischemic regions are shown by red arrows and regions at risk of infarction are shown by white arrows.*

**Conclusions:** Independent component analysis of DSC-MRI data has potential to identify hypo-perfused regions in AIS. ICA based assessment AIS can be achieved without AIF detection and explicit parameterization of the DSC perfusion data.

**References**: [1] Suzuki K et al, J Neuroimaging. 2011, 21(4):384-94. [2] LaViolette PS et al, ISMRM 2011:p789. [3] Cardoso J-F, et al., 1993, IEE Proceedings F, 140(6). [4] http://perso.telecom-paristech.fr/~cardoso/Algo/Jade/jadeR.m