

Robust Semi-Automated Arterial Input Function Identification Using Self Organizing Maps

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PURPOSE

Absolute quantification of cerebral blood flow (CBF) and volume (CBV) using dynamic-susceptibility contrast MRI relies on deconvolution of the arterial input function (AIF) - commonly estimated from signal changes in a major artery. However, the presence of bolus delay and dispersion between the artery and the tissue can be a significant source of error in the estimation of the kinetic parameters. These effects can be minimized if a local AIF is used, although, its measurement is nontrivial. We present an automated technique to determine the local AIF by the selection of best-candidate arterial pixels using a Kohonen Self-Organizing Map (SOM). The technique is validated across five patients with three exams each.

METHODS

Whole brain images from dynamic susceptibility contrast (DSC) MR images for perfusion studies are acquired as per the protocol for cancer patients. The imaging set typically consists of 15 slices, at 50-75 time points after the tracer injection. A 4x4 self-organizing map (SOM) is trained using a subset of 5 images from the imaging set with an empirically selected set of training parameters (learning rate 0.005, Gaussian neighborhood with sigma 0.4, iterations 100). Once trained, the full 15 slice imaging set is tested with the resulting SOM. The imaging set was preprocessed to correct for any linear baseline shift in signal intensity. The output of the SOM is the prototypical vectors for the 16 classes and the classification of all pixels into these 16 classes. The SOM classification is a combined result of the difference in pattern formed by factors such as the time of arrival of the bolus, amount of signal intensity change, the rate of change (rise and drop) in signal intensity, and recirculation.

Visual examination of the prototypical vectors clearly delineates the class for arterial pixels. It is characterized by the earliest and steepest drop in signal intensity, followed by a recirculation pattern, as expected physiologically. A plot of the prototypical vectors for a typical imaging set is shown in Fig. 1. The red prototypical vectors indicate the arterial pixels. The blue prototypical vectors, similar to the red except for a lag, are the venous pixels. Both the primary class, representing the purest sample, and the secondary class, representing the least partial volumed sample, are shown. However, only the primary arterial class is used in subsequent perfusion analyses using singular value decomposition. The remaining vectors represent other tissues in the brain.

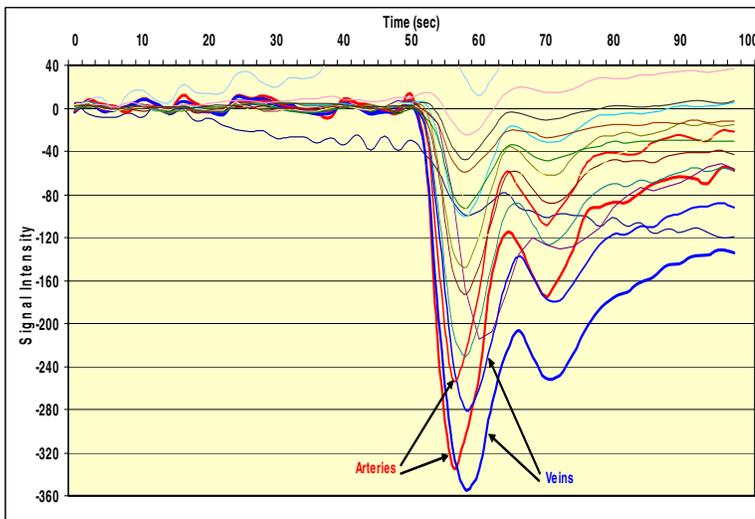


Fig. 1. Plot of the SOM output prototypical vectors for a typical imaging set. Arteries and veins are indicated on the plot.

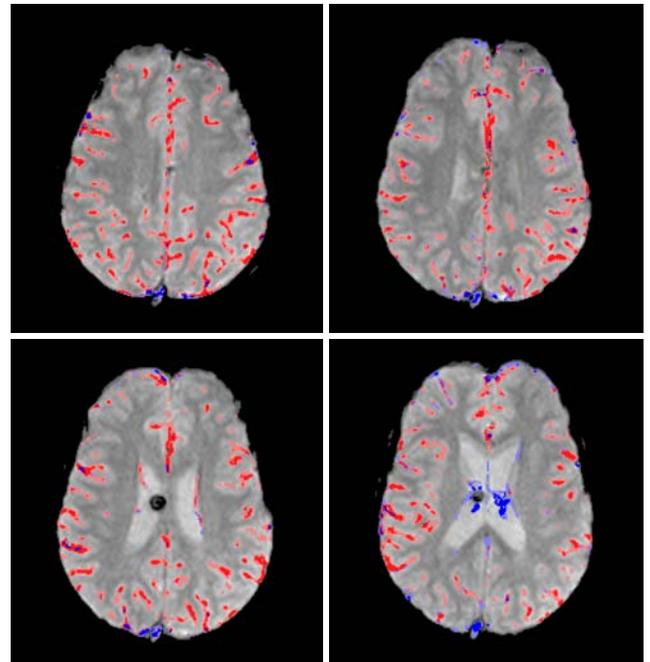


Fig. 2. Brain images with the arterial (primary class shown in red and secondary class shown in light red) and the venous (primary class shown in blue and secondary class shown in light blue) pixels overlaid across four slices.

RESULTS

Imaging data from five patients with three exams each were processed using this technique. In each of the cases, the technique performed robustly, yielding a unique class for the artery, separate from the vein. Fig. 2 shows the brain images with the arterial and the venous classes overlaid in red and blue respectively for a typical case. Lighter shades indicate partial volume pixels for arteries and veins. As seen, the SOM selects the pixels in the major as well as the peripheral arteries in the brain. Such an arterial function is the true arterial function representing the average of all arteries in the volume of interest.

CONCLUSIONS

Determination of the true arterial input function is central to any perfusion measurement and incorrect estimation of the AIF could lead to gross errors in the final parameters. Simpler techniques, typically used in literature, sample the AIF in the carotid artery. However, there is significant dispersion when blood flows into the peripheral arteries, thereby leading to errors. The SOM technique samples the AIF from the major and the peripheral arteries yielding the "true" local arterial function. Additionally, the sensitivity of the technique is underlined by the delineation of the arterial and venous pixels in separate classes. CBV and CBF calculations using the AIF obtained from this technique have yielded values close to those reported in literature and will be useful in normalizing results over various exams and patients.

REFERENCES

- Ostergaard, L., et. al., High resolution measurement of cerebral blood flow using intravascular tracer bolus passages. *Magn Reson Imag*, 36:715-736, 1996.
Part I: Mathematical approach and statistical analysis.
Part II: Experimental comparison and preliminary results.