Spatiotemporal patterns of physiological signals observed on dynamic brain MR images

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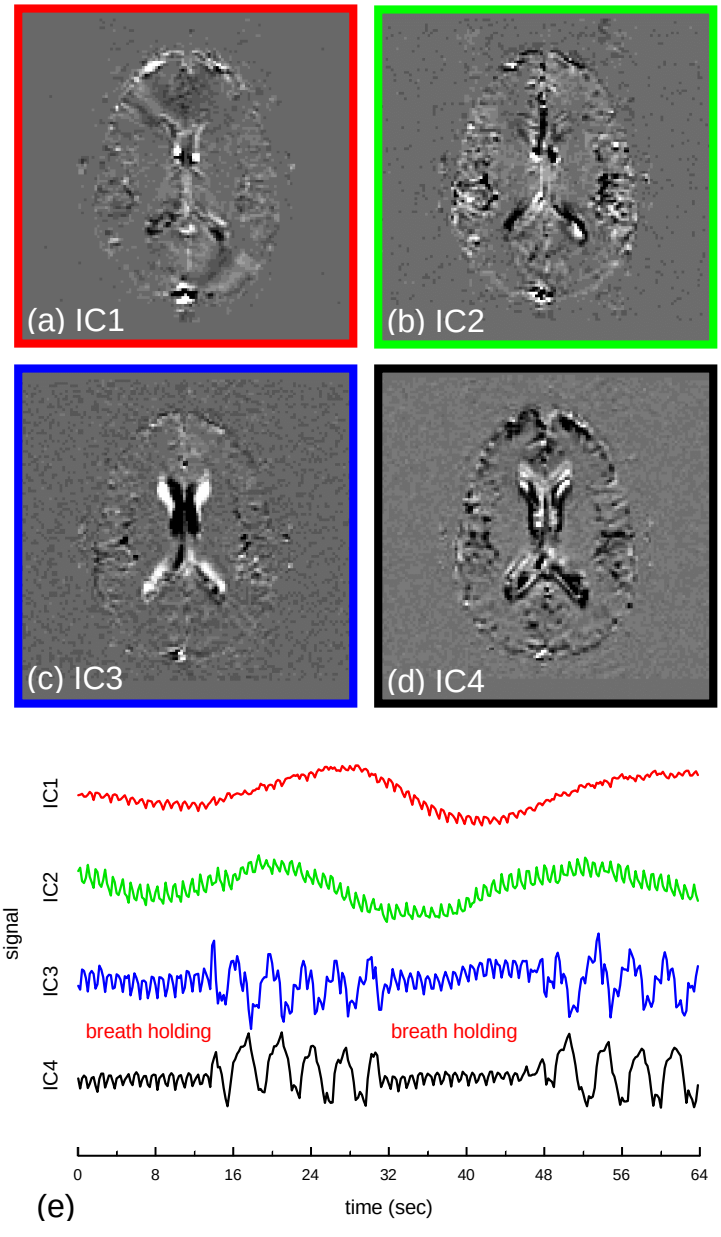
Introduction: Dynamic echo planar images are frequently acquired for functional MRI studies. Signals with respiration or cardiac rhythms observed on these images are considered as artifacts and many techniques are developed to remove them. Two more low-frequency signal variations called B and C waves [1-2] are recently observed on these dynamic images [3]. These waves are characterized as vasomotor rhythms and they are also observed in system arterial pressure, ventricular fluid pressure, intracranial pressure, cerebral blood flow, and peripheral blood flow measurements. However, the exact mechanisms for these two waves are still unclear. A better understanding on these signals can help us to extend our knowledge in physiology and to improve the analysis of functional MRI data. We conducted a study to investigate these four physiological signals.

Materials and methods: A single-shot, gradient-echo, echo-planar-imaging pulse sequence was applied to five normal subjects to repeatedly obtain trans-axial resting status brain images on a 1.5-Tesla MR scanner. Scan parameters were: TE/TR = 60/200 ms, flip angle = 90 degree, field of view = 24 cm × 24 cm, image matrix = 128×128, slice thickness = 5 mm, one averaging, and 350 single-slice images were acquired in 70 seconds. One extra data set with a subject performing a breath-holding experiment during scanning was acquired to study the respiration effects on the physiological signals. The dynamic images were analyzed using mean and variance, Fourier transform, spectroscopic images, independent component analysis (ICA) [4-5], and region of interest measurements to demonstrate the spatiotemporal patterns of the physiological signals.

Results: Figures (a) – (d) are the four-output ICA images calculated from the data set of a 50 year-old male subject performing a breath-holding experiment. The corresponding signal-time curves are plotted in Figure (e). In the red and green curves, a low-frequency signal at 0.03 Hz corresponds to B wave is observed. In the blue and black curves, the effect of breath holding is dramatically demonstrated. These curves indicate that respiratory motion causes oscillations in CSF and results in flow-related enhancement on the MR images.



Discussion: We find that: (1) The physiological signals observed on the dynamic images are local phenomena; (2) cardiac signals are observed at pixels near intracranial vessels and cortical CSF space; (3) respiratory signals are observed at pixels near cortical CSF space; (4) respiration-related signal variation at ventricle can be modulated by breathing; and (5) B and C waves appear at vessel areas. Our results also suggest B and C waves are physiological phenomena if they are seen at vessel areas. Further investigations on a larger sample size for gender- and age-related difference in both normal and patients group are anticipated. Moreover, whole brain imaging may provide an opportunity to further investigate the global effects of these physiological signals.

References:

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