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The Neural Correlates of Heart Rate Variability

Davar Ali*
Department of Cardiology, Ataturk University, 25030 Yakutiye, Turkey

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The morphology of the grey matter and its relationship to HRV can be evaluated using T1-weighted magnetic resonance imaging (MRI) with volumetric comparisons of manually, semi-automatically or automatically delineated neuroanatomical regions of interest, or with automated computerized techniques such as voxel-based morphometry (VBM) and cortical thickness measures. The VBM method hypothesizes that the gray matter volume of each brain region can be quantified by calculating the sum of all the voxels classified as gray matter. Assessment of cortical thickness with T1 -weighted images is a methodological alternative to VBM measurements, especially in detection of small cortical changes.

The relationship between brain activity in different regions and HRV can be evaluated using functional magnetic resonance imaging (fMRI). This method shows time-varying regional changes in brain metabolism, which can arise from different task-induced cognitive and emotional state changes or be the result of changes in the brain during the resting state. Changes in blood flow and blood oxygenation in the brain are closely linked to neural activity and are called "hemodynamic responses." Neuronal activity causes an increase in local cerebral blood flow (CBF) and oxygenated blood displaces deoxygenated blood and generates the blood oxygen level dependent (BOLD) MRI signal. Importantly, both vascular and neural mechanisms underlie the BOLD signal. Therefore, in addition to reflecting neural activity, the BOLD signal also reflects changes in other hemodynamic responses such as CBF, cerebral blood volume and the cerebral metabolic rate.

The key component of the BOLD signal is a hemodynamic response function (HRF), measurable as the transient signal change arising after a short stimulus and represents a fixed coupling between neural activity and the subsequent local hemodynamic response. The temporal structure of the HRF differs across brain regions and between subjects. These inter individual differences can be investigated by three parameters that characterize the HRF: response height (RH), time-to-peak (TTP) and full-width at half-max (FWHM). Alterations in CBF can be evaluated using an injected contrast agent and perfusion weighted MRI or using arterial spin labeling, which allows real time, non-invasive, quantitative assessment of cerebral perfusion. The main postulate of CBF assessment, using arterial spin labeling, is that what is measured is the delivery of blood to the capillary bed and, hence, a property of the tissue itself. This method is characterized by a poorer signal-to-noise ratio (a measure that compares the level of a desired signal to the level of background noise) than BOLD-based fMRI. However, in some cases, this method is favoured over BOLD-based fMRI, for example, for tasks, which are sporadic or longer than a few minutes. Investigation of neural correlates of resting HRV are important, because HRV at rest is a commonly used surrogate for the functioning and health of the autonomic nervous system and the resting state is the least confounded [1-3].

Conclusion

The results of studies performed using magnetic resonance imaging confirm that HRV measures associated with cardiac vagal and sympathetic control can be linked with the volume, activity and connectivity of specific brain regions. Our findings provide support for the interconnection of the brain and the heart by both structural and functional networks and indicate complex multi-level interactions.

Keywords: Heart rate variability; VBM; MRI

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****Corresponding author:*** *Davar Ali, Department of Cardiology, Ataturk University, 25030 Yakutiye, Turkey, Tel: +9136578629; E-mail:* davarali@gmail.com

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