Department of Anatomy
(Gross Anatomy and Neuroanatomy)

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General Summary

Our department research activities have focused on neuroanatomy and gross anatomy. In neuroanatomical research, organizations of neuronal networks and the development are investigated to elucidate brain function and diseases using morphological and electrophysiological methods. Our primary interest is focused on quantitative architecture and dynamics of neural circuits and their relationship. In gross anatomical researches, functional importance is explored on variations of organ systems using cadavers and animals.

Research Activities

To integrate and broadcast neural information, local microcircuits and global macrocircuits interact within certain specific nuclei of the central nervous system. The structural and functional architecture of this interaction was addressed for the caudal nucleus of the tractus solitarius (NTS), a relay station of peripheral viscerosensory information processed and conveyed to brain regions concerned with autonomic-affective and other interoceptive reflexive functions.

Spatiotemporal structure and dynamics of spontaneous oscillatory synchrony in the vagal complex

Fundamental structure and dynamics of spontaneous neuronal activities without apparent peripheral inputs were analyzed in the vagal complex (VC), whose activities had been generally thought to be produced almost passively to peripheral cues. The analysis included the caudal nucleus of the tractus solitarius — a main gateway for viscerosensory peripheral afferents and dynamically and critically involved in cardiorespiratory brainstem networks. In the present study, a possibility of self-organized brain activity was addressed in the VC. While VC neurons exhibited sparse firing in anesthetized rats and in in vitro preparations, we identified peculiar features of the emergent electrical population activity: (1) Spontaneous neuronal activity, in most cases, comprised both respiration and cardiac cycle components. (2) Population potentials of polyphasic high amplitudes reaching several millivolts emerged in synchrony with the inspiratory phase of respiratory cycles and exhibited several other characteristic temporal dynamics. (3) The spatiotemporal dynamics of local field potentials, recorded simultaneously over multiple sites, were characterized by a stochastic emergence of high-amplitude synchrony. By adjusting amplitude and frequency (phase) over both space and time, the traveling synchrony exhibited varied degrees of coherence and power with a fluctuating balance between mutual oscillators of respiratory and cardiac frequency ranges. Full-fledged large-scale oscillatory synchrony over a wide region of the VC emerged after achieving a maximal stable balance between the two oscillators. Distinct somatic (respiratory; ～1 Hz) and visceral (autonomic; ～5 Hz) oscillators seemed to exist and communicate co-operatively in the brainstem network. Fluctuating oscillatory coupling may reflect varied degrees of synchrony influenced by the varied amplitude and frequency of neuronal activity in the VC. Intranuclear micro-, intrabulbar meso-, and wide-ranging macro-circuits involving the VC are likely to form nested networks and strategically interact to maintain a malleable whole-body homeostasis.

These two brainstem oscillators could orchestrate neuronal activities of the VC, and other neuronal groups, through a phase-phase coupling mechanism to perform specific physiological functions.

Publications

Kawai Y. Cooperative Phase Adaptation and Amplitude Amplification of Neuronal Activity in the Vagal Complex: An Interplay Between Microcircuits and Macrocircuits. *Front Syst Neurosci.* 2019 Dec 3; **13**: 72. doi: 10.3389/fnsys.2019.00072. eCollection 2019. PubMed PMID: 31849619; PubMed Central PMCID: PMC 6901686.