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Research report

Hemi-ovariectomies promote a decrease in the dendritic lengths of CA1 and CA3 neurons: A dimorphic effect of the cerebral hemispheres

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ABSTRACT

Certain structures of the central nervous system (CNS) are morphologically and functionally related to the ovaries. Ovariectomy has been used to study the functional role of the ovaries in the CNS, as well as the role of the CNS on the reproductive system. In the present study, the effects of left and right hemi-ovariectomy on the morphology of pyramidal neurons from the CA1 and CA3 regions of the ventral hippocampus were studied. During the estrus phase, female Long-Evans rats underwent either left and right hemi-ovariectomies or left and right sham surgeries. Three estrous cycles later, the animals were sacrificed, and their brains were processed in Golgi-Cox stain and analyzed by the Sholl method to calculate the dendritic length of the CA1 and CA3 neurons of the left and right hemispheres. The results indicate that the dendritic lengths of the basilar and apical arbors of the CA1 neurons from the left hemisphere were shorter after both left and right hemi-ovariectomy, while the CA1 neurons from the right hemisphere were not affected by either procedure. However, the basilar dendritic arbors of the CA3 neurons from both hemispheres were affected by right hemi-ovariectomy. The spine density only decreased in the apical arbors in the CA3 neurons from the left hemisphere of rats that underwent right hemi-ovariectomy. This study's results indicate that hemi-ovariectomy in adult rats changes in the morphology of the CA1 and CA3 pyramidal neurons in the ventral hippocampus and that there are dimorphic responses between the hemispheres.

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1. Introduction

In mammals, the ovaries are innervated by fibers of the sympathetic and parasympathetic systems, as well as by different sensory neurons, the somata of which are found in the nodose and dorsal root ganglia (Burden et al., 1983). Viral transneuronal tracing revealed that different structures in the central nervous system (CNS) innervate endocrine glands (Gerendai et al., 2005, 2009; Tóth et al., 2008) and that there is an asymmetrical connection consisting of primarily hypothalamic and limbic structures. The right and left ovaries are embryologically and histologically similar, but they exhibit differences in their anatomical connections and cyclic physiological control (Thomson et al., 2001). Briefly, the ovaries through the ovarian nerve plexus (ONP) and superior ovarian nerve (SON) send or receive information to the celiac superior mesenteric ganglia (CSMG). Via the spinal cord and vagus nerve, ascending information arrives to various pons and mesencephalic nuclei and then to the hypothalamus, including the paraventricular nucleus, lateral hypothalamus and dorsal hypothalamus (Fig. 1; Gerendai and Halász, 1997, 2001; Gerendai et al., 2000, 2005, 2009; Tóth et al., 2007; Domínguez and Cruz-Morales, 2011).

The most noteworthy and complex feature of the neural connections of the hypothalamus is that they are extensively bi-directional. The fornix connects the hippocampal formation to the septal, preoptic and medial mammillary nuclei. There are also two unidirectional efferent limbic pathways from the hypothalamus. The mammillo-thalamic tract projects from the mammillary nuclei to the anterior nucleus of the thalamus. The anterior nucleus of the thalamus then projects to the cingulate cortex, which completes the circuit of Papez by projecting back onto the subiculum of the hippocampus (Dougherty,

Abbreviations: CNS, central nervous system; CA1, cornu ammon 1; CA3, cornu ammon 3; Left-HOVx, left hemi-ovariectomy; LH, left hemisphere; Right-HOVx, right hemi-ovariectomy; RH, right hemisphere.

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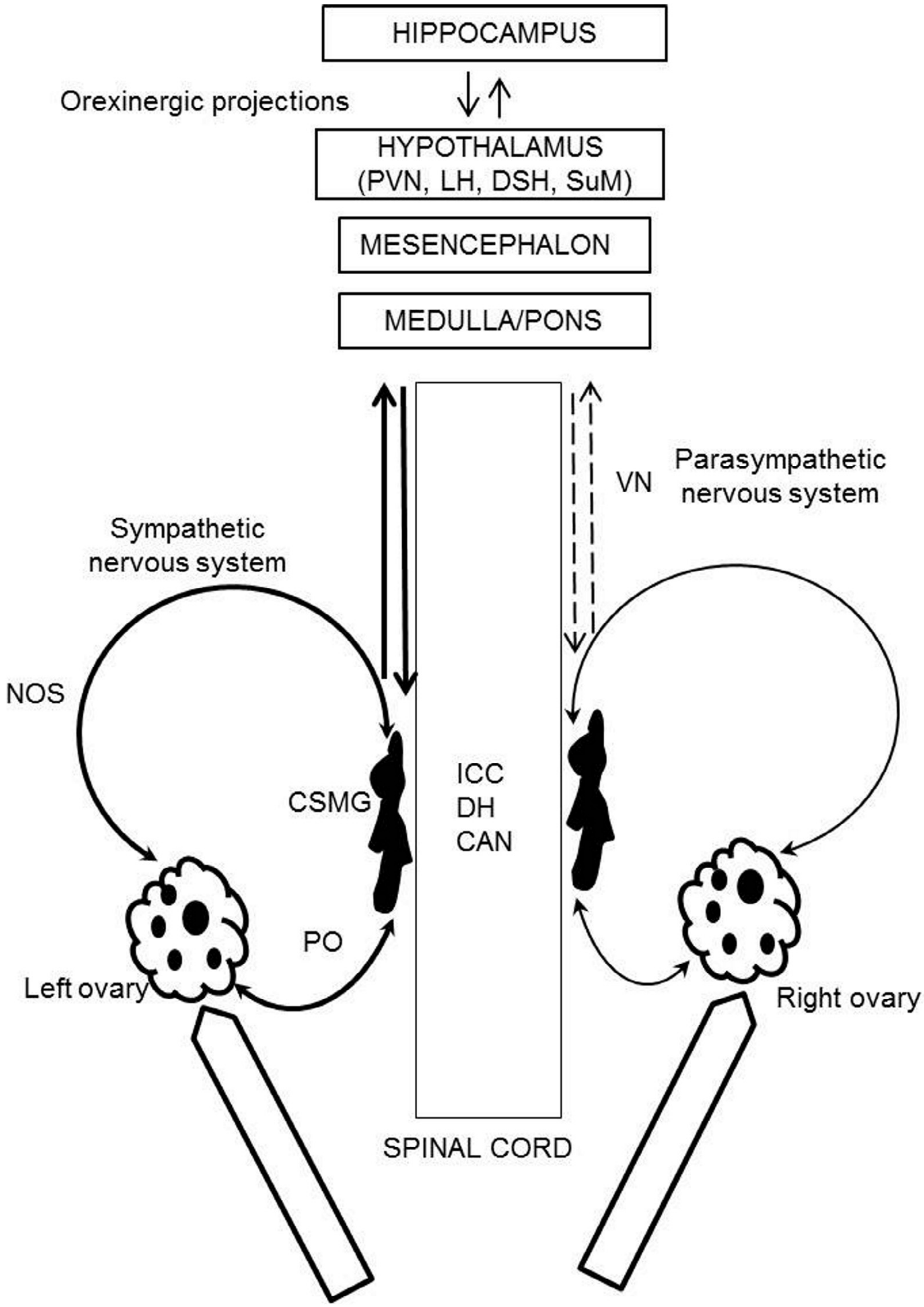

Fig. 1. Neural pathways between ovaries and the central nervous system (CNS). Both ovaries send information to the CNS through the sympathetic and parasympathetic nervous system, but the connectivity is larger between the left ovary and CNS (solid lines) than between the right ovary and brain (dotted lines). All information from the ovaries is sent through the Nerve Ovarian Superior (NOS) and Pelexus Ovarian Nerve (PO) to the Celiac Superior Mesenteric Ganglia (CSMG), and then through spinal cord (ICC: Intermediolateral Cell Column; DH: Dorsal horn; CAN: Central Autonomic Nucleus) and vagus nerve (VN). Afterwards, the information arrives to the pons nuclei (Parapyramidal Nucleus; Area Postrema; Nucleus of the Solitary Tract; Nucleus Ambiguous; Dorsal Vagal Complex; Cell Group; A5 Cell Group, A7 Cell Group; Raphe Obscurus; Raphe Pallidus; Raphe Magnus; Barringtońs Nucleus; and Locus Coeruleus), mesencephalon (Periaqueductal Gray) and hypothalamus (PVN: Paraventricular Nucleus; LH: Lateral Hypothalamus; DSH: Dorsal Hypothalamus; and SuM: Supramammillary nucleus). The hypothalamus has bidirectional connectivity with hippocampus.

2007). Outputs from the hippocampus primarily occur through the fornix. These fibers project to the mammillary bodies via the post-commissural fornix as well as to the septal nuclei, preoptic nucleus of the hypothalamus, ventral striatum and portions of the frontal lobe through the precommissural fornix (Swenson, 2006).

Additionally, the lateral hypothalamus extensively sends projections to different areas of the brain, including the hippocampus, through orexinergic projections. This diffuse orexinergic system regulates multiple complex physiological functions, such as feeding, arousal, sleep, stress, pain, addiction and memory processing (Parsania et al., 2016).

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