

Effects of Prenatal Alcohol Exposure on Basal Ganglia Development

Prenatal exposure to alcohol (ethanol) in humans and animals results in a range of alcohol-induced developmental defects. In humans, those collective birth defects are called Fetal Alcohol Spectrum Disorders, with the most severe manifestation being Fetal Alcohol Syndrome (FAS). FAS is defined by pre- and post-natal growth retardation, minor facial abnormalities, and deficiencies in the central nervous system (CNS). The basal ganglia, one of the central nervous system components, are affected by exposure to ethanol during development. When exposed to alcohol in utero, the basal ganglia decrease in size, which results in poor motor coordination and defects in executive functioning.

The basal ganglia are a cluster of specialized, densely-compacted masses of neurons located deep within the brain. That cluster is situated at the base of the cerebrum and abuts the thalamus. The basal ganglia act as a central hub of communication between the cerebrum, thalamus and other areas of the brain. Prenatal exposure to ethanol impacts some nuclei of the basal ganglia more drastically than others, resulting in a spectrum of motor coordination deficits.

The basal ganglia are composed of three bilateral clusters of nuclei: the caudate nucleus, the putamen, and the globus pallidus. The caudate nucleus is located closest to the cerebrum, and helps with voluntary motor coordination, memory, cognition, emotions, learning, and language comprehension. The putamen also aids in regulating movement and learning, but its other functions are not fully understood. The globus pallidus, at the core of the basal ganglia, is closest to the thalamus and contributes to both motor coordination and autonomous motor impulses. Other bilateral nuclei that are temporally grouped with the basal ganglia include the substantia nigra. The substantia nigra are located inferior and posterior to the basal ganglia and help to conduct neurological impulses to and from the basal ganglia, and may be involved in the reward-stimulus cycle.

Volumetric decreases in the basal ganglia were first observed in autopsies of rats that had been exposed to ethanol in utero. Currently, non-invasive neuroimaging techniques have made it possible to visually represent ethanol-induced defects in humans as well. Depending on the neuroimaging technique, those defects can be observed at any stage of life, from the prenatally affected child through the developmentally mature adult. Techniques used to image the basal ganglia include ultrasounds, magnetic resonance imaging (MRI), positron emission tomography (PET), and magnetoencephalography (MEG). With the aid of neuroimaging, overall anatomical structure of the brain and any physiological deficiencies can be inferred. Neuroimaging research has shown that in general there is an ethanol-induced volumetric decrease in the structures comprising the basal ganglia as well as the cerebrum and cerebellum in humans who have been prenatally exposed to alcohol. Among the nuclei of the basal ganglia, the caudate nuclei experience the most drastic volumetric decreases and morphological alterations resulting in a more hypoplastic structure.

The mechanisms responsible for those defects are not fully understood, however a decrease in the number of neurons formed and abnormal neural migration patterns may be partially responsible. Decreases in neuron numbers and changes to neuron migration patterns generally occur because of ethanol-induced developmental damage to the radial glia, a pool of neural progenitor cells that give rise to both neurons and glia in the CNS. Damages to that progenitor pool generally results in volumetric decreases throughout the CNS, and abnormal neuronal migration causes specific damage to the caudate nucleus.

Those ethanol-induced defects translate to a variety of motor coordination, cognitive, and behavioral

issues in the children affected. Children with basal ganglia defects may have problems with motor control in all stages of movement, from initial planning through execution. Those children may also have difficulties with spatial learning, awareness, and deficits in memory and verbal learning. Basal ganglia defects have also been associated with hyperactivity and impulsivity in children, which can at times be characterized as attention deficit disorders. Children with basal ganglia defects may also show an increase in perseverative behavior, which are repetitive actions an individual feels compelled to engage in, even in the absence of stimuli. Those behaviors are features of both obsessive compulsive disorders and autism spectrum disorders.

The effects of prenatal ethanol exposure on the developing basal ganglia can translate to a broad range of motor control, cognitive, and behavioral issues in affected children. Those occur as a result of overall volumetric decreases in the size of the nuclei due to issues with neuronal proliferation and migration. Neuroimaging technology has made it easier to pinpoint the specific areas that are most affected by those deficits, such as the caudate nucleus. Research continues with the goal that better understanding of basal ganglia defects may lead to better treatment plans for affected individuals.

Sources

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