

32 - 14. Neuroimaging and neurodevelopment

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© SPMM Course 14. Neuroimaging and neurodevelopment (This section is best read in conjunction with the section on neuroimaging in the Clinical Examination chapter) A neural tube is seen 2-3 weeks after the formation of the human fetus. By week 5, the ectodermal tissues differentiate to precursors of different brain regions. This is followed by birth neurons from stem cells (at ventricular proliferative zone, by week 8), neuronal migration (week 12-20), formation and pruning of axons, dendrites and synaptic contacts, myelination of axons and apoptotic removal of excess cells. One of the earliest neurodevelopmental events that can be visualized using neuroimaging in human fetuses is the migration of neurons. Around 17 weeks' of gestation, a transient layer of cortical subplate of migrating neurons is visible beneath the cortex; by 20 weeks the subplate withers away and replaced by more permanent cortical sheet at 24 to 28 weeks. A cortical folding pattern consisting of sulci and gyri become visible on fetal MRI by 20 weeks. Around the 28th week of gestation, the neuronal count in the human brain is at its peak - around 40% greater than in the adult. Dendritic formation accelerates at this time (but cannot be seen in MRI), and along with the disappearance of the proliferative zone and cortical subplate, an increase in cortical thickness is notable on fetal MRI. Synaptogenesis peaks around 34th week of gestation in (~ 40,000 new synapses formed per second) and continues in postnatal life alongside active synapse elimination; eventually the net number of synapses begins to decrease at puberty (pruning). Synaptic pruning cannot be observed directly with neuroimaging, but a prominent progressive cortical thinning of frontal and parietal cortices is noted in MRI studies during adolescence and is attributed to synaptic pruning. An indirect indicator of synaptic removal is the glucose metabolism measured using positron emission tomography (PET). Myelination of the visual cortical white matter begins prenatally (last trimester); by 9 months of postnatal life, myelination extends to frontal cortex (posterior-to-anterior maturation starting with sensory pathways motor pathways, and finally the higher-order association areas). Landmark longitudinal studies of brain volumes in children were conducted in the Child Psychiatry Branch of the NIMH, USA. These studies report the following observations

1. White matter volume increases linearly up to age 20 years in all brain regions;

2. Frontal, parietal, and temporal gray matter volumes follow an “inverted U-shaped” developmental curve (increase before adolescence, frontoparietal peak at 12 years and temporal peak at 16 years of age, followed by universal reduction thereafter)

© SPMM Course 3. The cortical thickness decreases with advancing age in “back-to-front” progression starting from sensorimotor areas, progressing to the dorsal parietal, superior temporal, and dorsolateral prefrontal cortices later. In other words, sensorimotor area mature earlier than higher-order regions. Cortical thinning may occur either due to synaptic pruning or myelination (with myelination, the brain tissue that is identified as white matter in MRI scans increase in proportion, reducing the relative grey matter thickness). Diffusion Tensor Imaging, a technique used to study the integrity of white matter tracts, reveals that in children, with advancing age, the directionality of diffusion in white matter pathways continues to increase especially in the prefrontal regions and in basal ganglia. This suggests that frontostriatal systems myelinate progressively during adolescence. DTI studies also show that the frontotemporal pathways may continue to myelinate until age 30 years. Magnetic Resonance Spectroscopic measure of N-Acetyl-Aspartate, an indicator of neuronal integrity, reveals low levels around birth that increase rapidly during the first 2 years of life, slowing down thereafter; this may represent synaptogenesis during childhood. Functional MRI studies reveal age-related increases in activation left frontal and temporal cortices (language areas) supporting the expansion of reading and phonological skills during childhood.

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