The Brain: Prenatal and Postnatal Effects of Congenital Heart Disease

Dianna M. E. Bardo, M D
Swedish Cherry Hill – Radia, Inc.
Seattle, WA
embryology

We recognize the VACTERL association and frequency of numerous anomalies or malformation in multiple organ systems which may be found in patients with congenital heart disease.

fetal brain growth and development depends upon an adequate supply of oxygen and other nutrients.

Major events in cardiac embryogenesis and in development of the brain and spinal cord occur at the same time, and cardiac malformation may affect brain development.
fetal cardiac development

precardiac cells form in the primitive streak

heart tubes form in the ventral midline

heart tubes fuse & begin to beat

heart looping

neural crest cell migration starts

dorsal & ventral endocardial cushions fuse

bulbar ridges & trabeculation are evident
fetal brain development

neural plate forms in the dorsal midline

neural tube forms & closes

neurulation

primary & secondary vesicles form at the rostral end of the neural tube

midbrain, cephalic & pontine flexures define brain regions

histiogenesis

telencephalon cells form anterior commissure & corpus callosum

telencephalon expands to form cerebral hemispheres

neural parenchyma

formation of cerebral fissures, gyri & sulci growth & differentiation

cells migrate from germinal matrix to cortex

cell migration, myelination

week 2          week 4                    week 7         week 11    term & beyond
neural plate forms in the dorsal midline

primary & secondary vesicles form at the rostral end of the neural tube

neural tube forms & closes

midbrain, cephalic & pontine flexures define brain regions
telencephalon cells form anterior commissure & corpus callosum
telencephalon expands to form cerebral hemispheres
formation of cerebral fissures, gyri & sulci

cell migration, growth & differentiation

cells migrate from germinal matrix to cortex

myelination

neurulation

histiogenesis

week 2  week 4  week 7  week 11  term & beyond
cardiac & brain development

important processes in development of multiple organ systems occur at the same time
cardiac & brain development

- branchial arch development
- aortic arch anomalies
- coarctation of the aorta
  - weeks 2-7

- heart looping
- TGA
  - weeks 4-5

- endocardial cushions form
  - weeks 4-5
- atrioventricular septal defect

- conal truncal malformation
  - TOF, TGA, DORV, truncus arteriosus
  - weeks 5-6
cardiac & brain development

neural tube formation & closure
  cephalocele, myelomeningocele
  Chiari malformation
  weeks 3-4

ventral induction & cell proliferation
  holoprosencephaly
  weeks 5-11

neurulation & histiogenesis
  agenesis of the corpus callosum
  weeks 6-7

neuronal proliferation, cell migration
  & cortical organisation
  cortical dysplasia
  weeks 11-T
postnatal brain development

After the brain is formed during the embryo stages, cell migration, differentiation, and growth continue throughout the remainder of gestation, throughout childhood, and well into adulthood.

It is postulated that postnatal brain growth is more important than fetal growth in determining cognitive function.

postnatal brain development
during normal development, critical periods of development occur in a predictable temporal sequence – each period is well documented and correlates with imaging findings:

- vision
- motor development
- language
- higher cognitive function

postnatal brain development

Children with severe forms of congenital heart disease are at high risk for a spectrum of neurocognitive difficulties, likely due to hypoxic-ischemic injury, including:

- Learning disabilities
- Behavioral problems
- Mental retardation

Risks are present prenatally, in the newborn (pre-operative, operative and postoperative), during infancy & childhood.
fetal brain perfusion

fetuses with severe forms of CHD have abnormal cerebral Doppler ultrasound indices

decreased cerebrovascular resistance is associated with poorer cognitive performance at 18 months of age

hypothesis – changes in fetal cerebral blood delivery, speculated that changes impact on cerebral development similar to that seen in fetuses IUGR

fetal cerebral perfusion
diminished MCA pulsatility index (PI) & lower cerebrovascular resistance with left-sided obstructive lesions
  • HLHS, AV stenosis, arch hypoplasia/coarctation, IAA
increased MCA PI & higher cerebrovascular resistance and elevated UA PI with right-sided obstructive lesions
  • TOF, PV stenosis/atresia, TV atresia, Ebstein’s hypothesis – autoregulatory decrease in cerebrovascular resistance leads to diminished oxygen delivery, which is not sufficient to meet cerebral metabolic demands
The Brain: Prenatal and Postnatal Effects of Congenital Heart Disease

Dianna M. E. Bardo, M.D.
Swedish Cherry Hill
Seattle, WA