Introduction

Transcranial ultrasound is the primary imaging modality employed in the assessment of neonatal and infant brain ***(Burton and Brody, 2010).***

In comparison with conventional neuroimaging methods (such as computed tomography or magnetic resonance), TCUS has the advantages of low costs, short investigation times, repeatability, and bedside availability ***(Caricato et al., 2014).***

Considering that most of the brain lesions are clinically subtle or silent during the neonatal period, a cranial ultrasound screening may play a role in: 1. detecting babies at risk of impaired neurodevelopment later in childhood and who may benefit from early intervention programs; 2. identifying the most significant perinatal risk factors associated with brain abnormalities in such a large low-risk population in order to target the potential need for cranial ultrasound at birth ***(Fumagalli et al., 2014).***

Improvements in critical care medicine have resulted in the increased survival of premature, low birth weight and asphyxiated infants. An integrated clinical and radiological approach to the neurological assessment of such neonates over the past few years has led to a better understanding of the cause and evolution of the cerebral lesions and thus allowed more appropriate medical intervention to favourably alter clinical outcome ***(Coni et al., 2015).***

It has proven diagnostic value in detecting the most common brain lesions in premature neonates; such lesions include those due to intraventricular hemorrhage and white matter disease ***(Burton and Brody, 2010).***

Cranial ultrasonography (US) plays an important role in the initial evaluation of an infant with suspected bacterial meningitis as well as in monitoring all possible complications. It can help to differentiate brain tumors from other mass like lesions and narrow the differential diagnosis***(Coni et al., 2015).***

In the neonatal period, cranial US can be used as the initial modality to exclude a major structural malformation. Familiarity with the US features of congenital brain anomalies is therefore an extremely valuable tool, as it facilitates an accurate diagnosis and treatment when necessary ***(Vasiljevic et al., 2012).***

Color and duplex Doppler sonography, as a safe and a feasible method, have broadened applications in evaluation of pediatric cerebral vascular anatomy and perfusion. It candetermine any alterations occurred in the neonatal cerebral circulation that could result in brain damage and adverse developmental outcomes***(YING-CHIN et al., 2013&Burton and Brody, 2010).***

Establishment of the predictive validity of cerebral blood flow measures by Doppler ultrasound is essential to ensure their usefulness in the early assessment and interpretation of hemodynamic changes***(Ying-Chin et al., 2013).***

Aim of the Work

Is to demonstrate the role of transcranial and color Doppler ultrasound as a bed-side safe neuroimaging technique in diagnosis of common brain insults in this age group.

Chapter (1)
Anatomy of the Brain

Components of the central nervous system

The central nervous system (CNS) consists of spinal cord and brain. Brain is further subdivided into medulla, pons, midbrain, cerebellum, diencephalons and cerebral hemispheres. Within each of the seven central nervous system divisions resides a component of the ventricular system; a labyrinth of fluid filled cavities. Neuronal cell bodies and dendrites are located in cortical areas (located primarily on the surface of cerebral hemispheres) and in nuclei which are clusters of neurons located beneath the surface of all of the central nervous system divisions ***(Brodal, 2004).***

Development of the brain

The key to understanding the complex anatomy of the mature brain is to understand how it develops.

The cellular constituents of the central nervous system - neurons and glial cells - are formed from a specialized region of the ectoderm called the neural plate. ***(Stiles and Jernigan 2010).***

The neural plate lies along the dorsal midline of the embryo. Proliferation of cells is greater along the margin of the neural plate than along the mid line, resulting in the formation of the neural groove. This midline indentation deepens gradually and closes to form the neural tube .Formation of the neural tube begins during the early part of fourth week (fig1) ***(Brodal, 2004).***

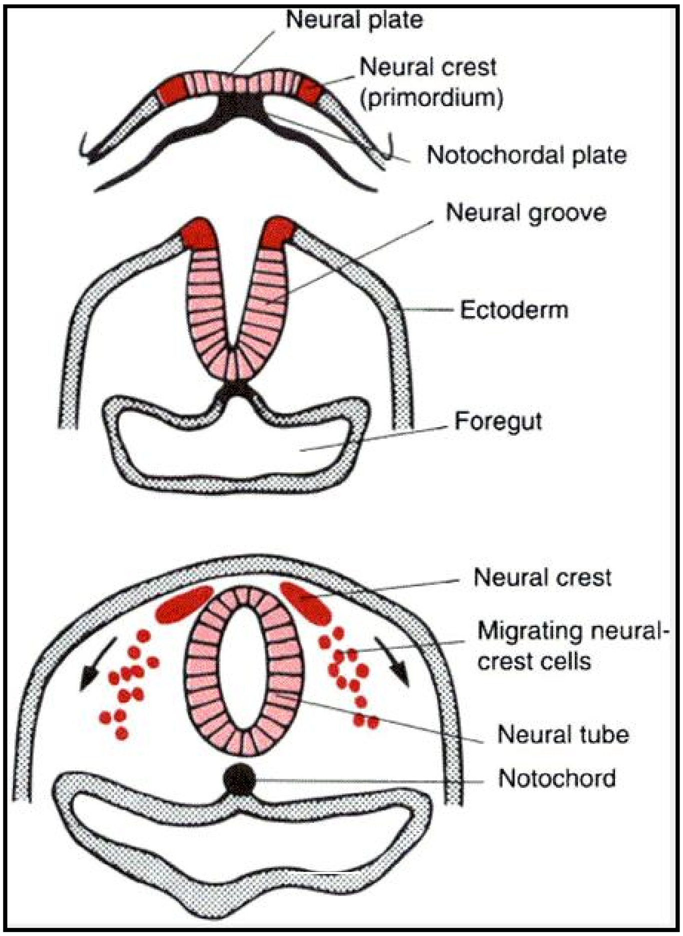

Figure (1): Formation of the neural tube *(Quoted from Brodal, 2004).*

Lining the neural tube is the ventricular zone which consists of epithelial cells that generate virtually all neurons and glial cells.

The caudal portion of the neural tube forms the spinal cord, and the rostral portion becomes the brain. The cavity within the neural tube forms the ventricular system. Closure of the neural tube occurs first at the location where the neck will form and then proceeds both caudally and rostrally.

Very early in development the rostral portion of the neural tube forms the three primary brain vesicles. The three primary brain vesicles form the:

Forebrain (prosencephalon)

Midbrain (mesencephalon)

Hindbrain (rhombencephalon)

During the fifth week the forebrain partly divides into two secondary vesicles, the telencephalon and diencephalon; the midbrain does not divide; the hindbrain partly divides into metencephalon and myelencephalon; consequently, there are five secondary brain vesicles (fig2) (Brodal, 2004).

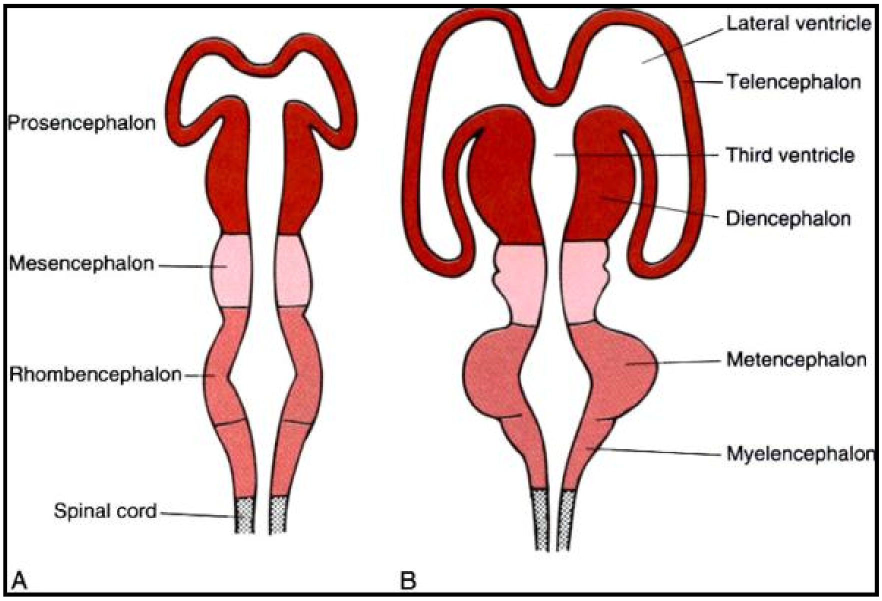

Figure (2): Different divisions of the brain primordium. Note the development of the telencephalon (the hemispheres) that gradually covers the diencephalon. ***(Quoted from Brodal, 2004).***

The telencephalic vesicles are the primordia of cerebral hemispheres, and their cavities become the lateral ventricles.

The cortex is formed from neuroblasts that are generated in the germinal matrix, an ependymal layer of the ventricular wall. The neuroblasts migrate to the surface of the brain supported by radial glial-neuronal units, passing neurons previously laid down to form the first layers of cortex. Thus the six layers of the cortex are formed with the youngest neurons on the surface and the oldest ones adjacent to the subcortical white matter.

The migration of the neuroblasts starts at about week 7, is most intense during weeks 15-17, and is largely completed by weeks 23-24. When the process of neuronal migration is disturbed, there is a migration disorder**.**

Initially the surface of the hemispheres is smooth; however, as growth proceeds, sulci and gyri develop. The sulci of the cerebral hemispheres appear from the fourth month of gestation and at the full term the general arrangement of sulci and gyri are present but the insula is not completely covered **. *(Stiles and Jernigan 2010).***

The *diencephalon* will differentiate into thalamus and hypothalamus. The cavities of the telencephalon and diencephalons contribute to the formation of the third ventricle, although the cavity of the diencephalon contributes more. The midbrain undergoes less change than any other part of the developing brain, except for the most caudal part of the hindbrain. The neural canal narrows and becomes the cerebral aqueduct, a canal that connects the third and fourth ventricles.

The walls of the metencephalon form the pons and cerebellum, and the myelencephalon becomes the medulla oblongata. The cavity of the hind brain becomes the fourth ventricle and the central canal in the caudal part of the medulla ***(Brodal, 2004).***

Anatomy of the brain

Neonatal skull

The calvarial bones are thin at birth and ossification does not extend to suture lines of the skull. The junctions between the calvarial bones are the sites of the fontanelles.

Six fontanelles are present at birth; anterior and posterior fontanelles are median, paired sphenoid and mastoid fontanelles are lateral.

The largest fontanelle is the anterior: it has average diameter of 25 mm at birth. It overlies the superior sagital dural venous sinus which transmits its pulsations to overlying skin**.**

The anterior fontanelle, located at the junction of the coronal and sagittal sutures. The midline posterior fontanelle, located at the junction of the lambdoid and sagittal sutures. and mastoid fontanelle is located at the junction of the squamosal, lambdoid, and occipital sutures ***(Burton and Brody ,2010).***

Obliteration of the fontanelles occurs with progressive growth of edges of the bones that form their borders. Sphenoid is obliterated by 6 months; the anterior and mastoid are obliterated by the second year ***(Burton and Brody ,2010).***

While the posterior fontanelle closes somewhat earlier by about 3 months of age (fig 3) ***(Burton and Brody ,2010).***

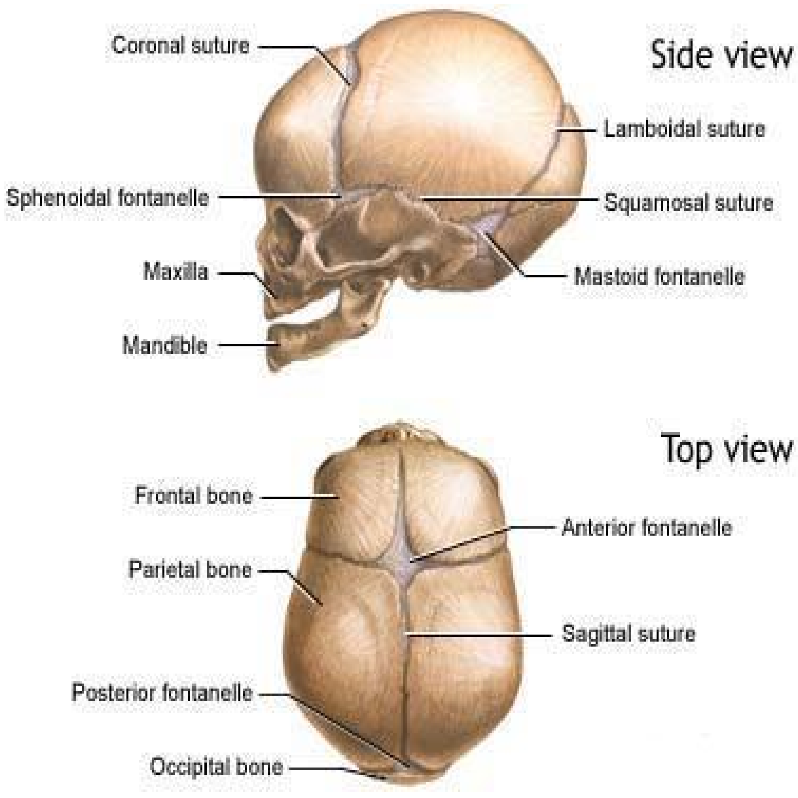

Figure (3): Skull at birth side and top views. ***(Quoted from Burton and Brody ,2010).***

Cerebral hemispheres

The cerebral hemispheres are the most highly developed portions of the human central nervous system. Each has four major components: cerebral cortex, hippocampal, amygdale, and basal ganglia (fig 4) ***(Ribas 2010).***

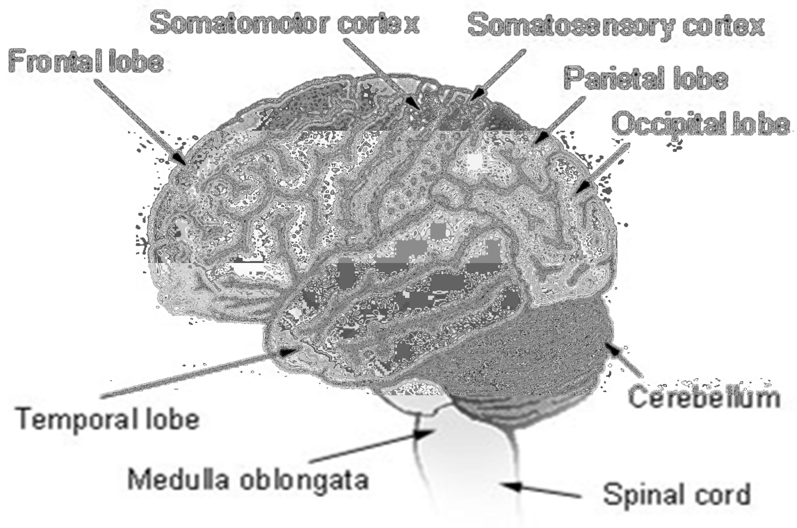

Figure (4): Lobes of the cerebrum ***(Quoted from Burton and Brody 2010)***

Cerebral cortex:

The superolateral surface of each cerebral hemisphere has two deep sulci, they are: The lateral sulcus, also known as Sylvian fissure, which separates the frontal and temporal lobes; The central sulcus (of Rolando), which passesupwards from the lateral sulcus to the superior border of the hemisphere. This separates the frontal and parietal lobes. The central sulcus is located further rostrally in full term neonates while the lateral sulcus is more oblique in full term neonates than in the adult. The parieto-occipital sulcus on the medial surface of hemisphere separates the parietal and occipital lobes**. *(Ribas 2010).***

Insular cortex is buried beneath the frontal, parietal and temporal lobes.

The corpus callosum

Corpus callosum contains axons that interconnect the cortex on the two sides of the brain. Tracts containing axons are called commisures, and the corpus callosum is the largest of the brain's commisures.***(Aribandi and Bazan, 2004).***

(Luijkx et al., 2015).

The Brain stem

The midbrain, pons, and medulla oblongata comprise the brain stem.

The midbrain consists of two halves called the cerebral peduncles. The tectum located behind the cerebral aqueduct. It has four small surface swellings called the superior and inferior colliculi.

The pons is found on the anterior surface of the cerebellum below the midbrain and above the medulla oblongata.

The medulla oblongata extends from the pons to the foramen magnum, where it continues as the spinal cord. ***(Ribas 2010).***

The cerebellum

The cerebellum is composed of two hemispheres that have the appearance of cauliflower. The cerebellum lies in the posterior cranial fossa under the tentorium cerebelli. The two hemispheres are connected by the vermis. Three pairs of nerve tracts, the cerebellar peduncles connect the cerebellum to the brain stem. The superior cerebellar peduncles connect the cerebellum to the midbrain. The middle cerebellar peduncles connect the cerebellum to the pons and the inferior cerebellar peduncles connect the cerebellum to the medulla oblongata .***(Aribandi and Bazan, 2004).***

Cerebrospinal fluid:

The cerebral ventricular system and cerebrospinal fluid spaces

The cerebral ventricular system consists of the paired lateral and single third and fourth ventricles.

Cerebrospinal fluid (CSF), is produced in the choroid plexuses, and most of it is in the lateral ventricles, entering medially through the choroidal fissures. It flows from the lateral ventricles to the third ventricle through the foramen of Monro, in the anterior portion of the roof of the third and from the third to fourth via the cerebral aqueduct of the midbrain. From the fourth ventricle, the CSF enters the subarachnoid spaces, leaving through the paired foramina of Luschka, laterally and the midline, single foramen of Magendie. At the base of the brain, there are relatively large CSF spaces, the basal CSF cisterns, which are important both anatomically and in CT or MRI diagnosis. Although named individually, according to adjacent structures, they