Anesthesia for Neurosurgery in Infants and Children

ESSAY

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Master Degree in Anesthesiology

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List of Acronyms

AVM Arteriovenous Malformation

BBB Blood Brain Barrier

CBF Cerebral Blood Flow

CBV Cerebral Blood Volume

CMR- reducing anesthetics Cerebral metabolic rate reducing agents

$CMRO_2$ Cerebral Metabolic Rate for Oxygen

COP Cardiac Output

CPP Cerebral Perfusion Pressure

CR Crown Rump

CSF Cerebro Spinal Fluid

CT Computed Tomography

CVP Central Venous Pressure

EBV Estimated Blood Loss

ED Emergency Departement

EEG Electroenchephalogram

ET CO_2 End Tidal Carbon Dioxide

FAST Focused Assessment by sonography for Trauma

GCS Glasgow Coma Scale

ICP IntraCranial Pressure

INR	International Normalized Ratio
LMA	Laryngeal Mask Airway
LR	Lactated Ringer
MABL	Maximal Allowable Blood Loss
MAC	Minimum Alveolar Concentration
MAP	Mean Arterial Pressure
PAP	Pulmonary Artery Pressure
PEEP	Positive End Expiratory Pressure
POCA	Perioperative Cardiac Arrest
PT	Prothrombin Time
$PtiO_2$	Brain tissue Oxygen Pressure
PTT	Partial Thromboplastin Time
PVO_2	Jugular Venous Oxygen Pressure
RIS	Rapid Infusion System
SA node	Sinoatrial node
SAH	Subarachnoid Hemorrhage
SCPP	Spinal Cord Perfusion Pressure
SIADH	Syndrome of Inappropriate Antidiuretic Hormone secretion
$SjVO_2$	Jugular Venous Oxygen Saturation
SVP	Superior Vena Cava

TBI	Traumatic Brain Injury
T-Echo	Transesophageal Echocardiography
WFNS	World Federation of Neurosurgeons

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Abstract

Anesthesia for neurosurgery is an important topic specially in infants.

Before going through, the anesthetist must know the physiology of ICP and how to control.

Factors affecting CSF formation , what increases and what decreases are also important to be known.

Neurosurgery specially in infants has critical hazards as bleeding and venous air embolism that should be prevented and well treated if happened.

The anesthetist should take care of life threatening problems in certain neurosurgical procedures such as bleeding in craniostenosis …..etc.

Key word:

Neurosurgery

Anesthesia

infants

Anatomy

Neurologic changes observed in maturing infants and children are ultimately related to morphologic and biochemical events in the brain.

❖ *Neuroembryology and development:*

The CNS is the system first to begin and probably last to complete its development in human maturation.

The processes by which the CNS develops follow three steps:

(1) neurulation, (2) canalization, and **(3) retrogressive differentiation.**

Before discussing the steps, the ***Carnegie staging system*** should be mentioned. It is an accurate method of assessing maturity of the embryo based on a series of developing external and internal features combined with the Crown-Rump (CR) measurement. This system describes a series of 23 stages that take place during the embryonic period, i.e. the first 8 weeks of development.(1)

1) Neurulation

A- Early development of the neural tube:

(Early stage of neurulation in humans):

The process by which the neural tube initially folds is called neurulation.(1)

Neural tube differentiation is a part of a long process of neurologic development, which occurs in the first 56 to 60 days after fertilization of the ovum. The nervous system does not appear until stage 6 (i.e., during the second week of gestation).(2)

Primary orientation of the embryo arises when the primitive streak and Hensen's node are present. Shortly thereafter, the notochord is found extending rostrally from Hensen's node. Over the next 2 days, when there are six or seven somites, fusion of the neural folds occurs (stage 10). Initial site fusion occurs at the level of the third or fourth somite, which correlates with the future rhombencephalon (hindbrain) region. By early stage 11, the embryo possesses fused neural folds to the level of the colliculi rostrally. The primordia of the thalamus and corpus striatum distort the terminal hole and may be involved in its closure. At this time, the only contact between the neuroectoderm and the amniotic cavity is through the posterior neuropore.(2)

B- Later Development of the Neural Tube

- ***Cerebral Cortex and Cerebellum:***

After closure of the anterior neuropore in stage 11, there is an interval before the first indication of differentiation of the telencephalon (forebrain). The anlage of the cerebellum are found when the pontine and cervical flexures begin to form during stage 13.[2,3]

In stage 15, bilateral cerebral vesicles appear, and their connections with the existing neural tube later become the foramina of Monro. The midline lamina terminalis forms a keel to these enlarging structures. The deep cerebral nuclei, which are derived from the diencephalon (midbrain), appear at different stages. The thalamic structure begins to appear at stage 15, with a separate lateral part becoming identifiable later.[2,4]

By stage 17, areas that become frontal and parietal lobes are identifiable. Primordia of the occipital lobe are present at stage 19, and the temporal pole appears at stage 23 (Fig.1).

At this early stage, these poles bear no resemblance to their final form. The main differentiation of the cerebral cortex takes place throughout the gestational period but mainly during the third trimester.

The external surfaces of the developing brain provide information about gestational age. Fissures and sulci develop. A majority of the cortical surface becomes buried as the gyri are formed. The primordium of cortical gray matter is formed when a layer of neuroblasts, derived mainly from pyramidal cells, migrates into the marginal zone during stage 22. The progressive formation of upper and lower fibers divides the caudate nucleus from the Putamen and the Globus pallidus at stage23.[4]

Table (1): Phases and stages of neural development (2)

Phase	Stages	Age (days)	Outcome
Neurlation	7	16-28	Brain, spinal cord through 12-1L
Canalization	13-20	30-52	Sacral, coccygeal segments
Retrogressive differentiation	180birth	46birth	Filum terminale

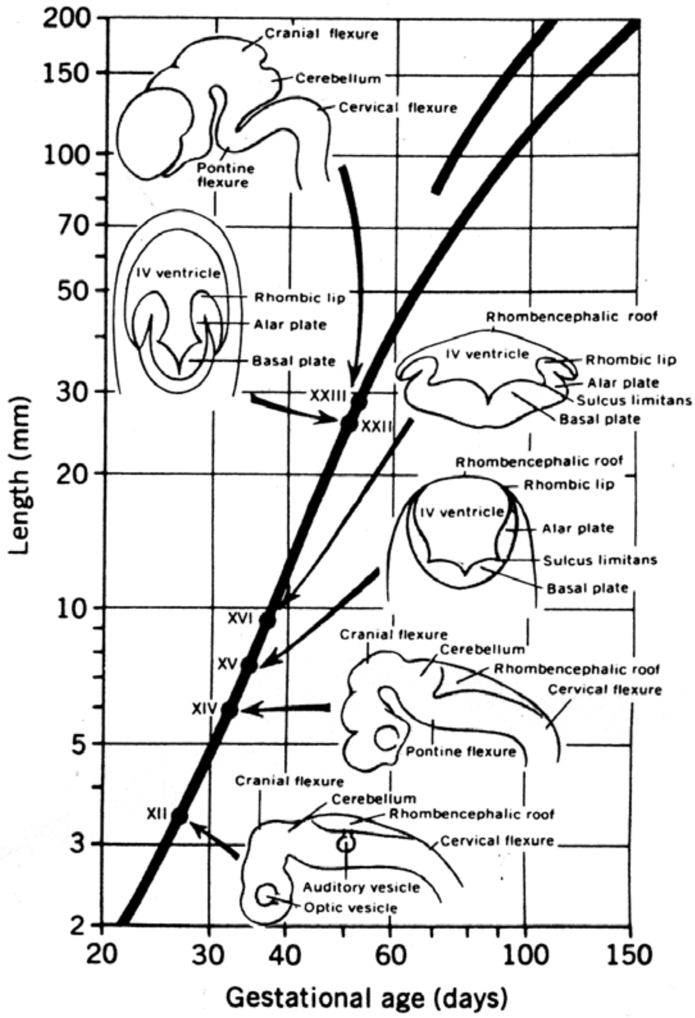

Fig. (1): *Schematic representation of early development of the human cerebellum as correlated with developmental stage (Roman numerals), gestational age, and crown-rump length.*[4]

Early development of the cerebellum takes place about 1 month after the embryonic period begins, even though the paired cerebellar primordia have not acquired a recognizable pattern. Development of the cerebral cortex and the white matter is relatively primitive by the time of transition from embryo to fetus. This supports the concept that the brain grows mainly during the later phases of gestation and will be continued postnatally.

2) & 3) Canalization and Retrogressive Differentiation:

The process of neural tube formation that occurs caudal to the neural tube formed by neurulation is called ***canalization*** and involves development of the lower lumbar, sacral, and coccygeal segments. Cells proliferate in the neural tube wall in this region. This "**secondary**" phase of caudal neural tube development and the development of the associated vertebrae produce an excess number of segments.

Formation of the filum terminale and the cauda equina is the result of ***retrogressive differentiation***. It consists of a degenerative process in which the excess segments formed by canalization are remodelled. It eventually brings the conus medullaris to its adult level opposite L1-L2.[2]

The Ventricular System and Cerebrospinal Fluid Pathway:

When closure of the posterior neuropore occurs in stage 12, the ventricular system is closed and consists of that within the prosencephalon, diencephalon, mesencephalon, rhombencephalon (metencephalon, myelencephalon), and central canal of the spinal cord. During stage 14 the rhombencephalic roof becomes thinner, and in stage 15 evaginations of the cerebral hemispheres develop.

This demarcates the anlage of the lateral ventricles, the third ventricle, and the foramen of Monro. By stage 20 the cerebral hemispheres have overlapped the dien-cephalon.[2]

At this stage the lateral ventricles are the largest of the ventricular system. At about this stage a perforation of the roof of the fourth ventricle occurs, creating the foramen of Magendie. The foramina of Luschka form about 10 to 11 weeks later.

Within the cranium, the aqueduct of Sylvius narrows as the tectum and tegmentum enlarge. The actual volume within the lateral, third, and fourth ventricles becomes somewhat reduced as the choroid plexuses differentiate and the brain substance increases. The central canal of the spinal cord is normally obliterated after birth by the cellular proliferation of the spinal cord. Therefore, the ventricular system terminates in the caudal floor of the fourth ventricle.[2,3]

❖ ***Anatomy of the CNS:***

At birth the brain weighs about 335 g and accounts for 10 to 15 percent of total body weight. During the first year of life the brain grows rapidly. It is doubled in weight within 6 months and at 1 year weighs 900 g. At the end of the second year it weighs 1000 gm. It reaches adult weight by about 12 years of age (1200 to 1400 gm). The weight ratio of the CNS to the total body in adulthood is about 2 percent. The calvaria at birth consists of ossified plates, which cover the dura mater and are separated by fibrous sutures and the fontanelles.[2,4]

Two fontanelles are identifiable at birth. The posterior fontanelle closes during the second or third postnatal month, and the anterior fontanelle usually closes at 10 to 16 months .The fontanelles do not totally ossify until the teenage years. However, even before closure of the fibrous fontanelle, the ability to accommodate to an acute increase in ICP is limited, if not nonexistent. The distensibility of the dura mater and the osteofibrous cranium resembles that of a leather bag and offers a high resistance to an acute rise in pressure.[5]

Slow pressure rises can, to a certain point, be accommodated by expansion of the fontanelle and separation of the suture lines.

Palpation or application of a skin transducer on the fontanelles can be used clinically to assess ICP. The intracranial space is separated into two major compartments by a fold of dura called the tentorium cerebelli. This is a tent shaped dural fold which forms a roof over the posterior cranial fossa.

***The Supratentorial compartment*:**

The supratentorial compartment is the largest compartment of the craniospinal space and includes both the anterior and middle cranial fossae. Its size is determined by the calvaria and the tentorium cerebelli. The two hemispheres are separated by the falx cerebri. Each hemisphere consists of three lobes (frontal, temporal, and parieto-occipital), each of which has several complex and specialized functions. Lesions of the temporal and parieto-occipital lobes have more serious clinical consequences than lesions in the frontal lobe.[5,6]

The anterior cranial fossa is occupied by the inferior part of the frontal lobe. The middle cranial fossa lodges the basal part of the temporal lobe. Between the anteromedial parts of the right and left leaves of the tentorium is an oval opening called the tentorial incisura (notch). It allows the brain stem to pass from the middle cranial fossa to the posterior cranial fossa.

The diencephalon forms the central part of the supratentorial compartment and is the rostral end of the brain stem. It consists of the thalamus, hypothalamus, epithalamus, and subthalamus, and it surrounds the third ventricle. It is vulnerable to involvement by neoplasms and ischemia.[2]

***The Infratentorial compartment*:**

The posterior cranial fossa is the largest and deepest of all three cranial fossae. It contains the cerebellum, pons , and medulla oblongata. The cerebellum occupies most of the posterior cranial fossa and is mainly concerned with motor functions that regulate posture, muscle tone, and coordination. Midline or bilateral lesions on the cerebellum may cause unsteady gait, hypotonia and tremors.