Introduction

The central nervous system (CNS) consists of the brain and the spinal cord. The brain is composed of 3 main structural divisions: the cerebrum, the brainstem and the cerebellum. At the base of the brain is the brainstem, which extends from the upper cervical spinal cord to the diencephalon of the cerebrum. The brainstem is divided into the medulla, pons and midbrain. Posterior to the brainstem lies the cerebellum ***(Anand et al., 2013).***

Traumatic brain injury (TBI) remains the leading cause of death and long-term disability in people younger than 40 years worldwide ***(Ross et al., 2011).*** Traumatic brain injury is a nondegenerative, noncongenital insult to the brain from an external mechanical force, possibly leading to permanent or temporary impairment of cognitive, physical, and psychosocial functions, with an associated diminished or altered state of consciousness ***(Segun, 2013).***

TBI is divided into two discrete periods: primary and secondary brain injuries. The primary brain injury is the physical damage to the parenchyma (tissue, vessels) that occurs during traumatic event, resulting in shearing and compression of the surrounding brain tissue. The secondary brain injury is the result of a complex process, following the primary brain injury in the ensuing hours and days. Secondary intracranial brain insults include cerebral edema, hematomas, hydrocephalus, intracranial hypertension, vasospasm, metabolic derangement, excitotoxicity, calcium ions toxicity, infections and seizures. Secondary, systemic brain insults are mainly ischemic in nature. Hence, it is now clear that only part of the damage to the brain during head trauma is from the primary brain injury, which is not amenable to alteration and cannot be reversed. However, secondary brain insults are often amenable to prevention or reversal ***(Samir et al., 2012).***

Intensive care management of patients with severe TBI comprises high quality general care and various strategies aimed at preventing or reducing secondary brain damage while the underlying pathology is resolving. The primary focus is to maintain the increase of ICP and to maintain adequate cerebral perfusion with oxygenated blood. The management should be individualized on the basis of physiological knowledge. In ICU, control of the factors involved in maintaining the cerebral perfusion pressure such as arterial and venous pressures, intracranial pressure and pCO2 is mandatory. Avoidance of metabolic derangements such as hyperglycemia and hyponatremia is also important and meticulous attention to all aspects of Critical Care management is a key factor in improving outcome after head injury ***(Arturo et al., 2013).***

AIM OF THE WORK

This essay aims to describe the basics of primary brain injury and then addresses the critical care strategies employed; to minimize secondary brain injury, to reduce morbidity and improve outcome.

ANATOMY AND PHYSIOLOGY OF THE BRAIN

The brain is the control center of the body; the functions of the brain include the coordination of our body's systems to maintain homeostasis; through processing body movements, personality, behavior and the senses. The most important homeostatic functions are breathing, heart rate, body temperature, and metabolic functions. Grossly the brain composed of the cerebrum, brain stem and the cerebellum (Figure 1) (***Martini et al., 2003).***

Structural Units and Overall Organization

The nervous system is composed of cells, called neurons that are specialized for information processing and transmission. Neurons make contact with each other at junctions called synapses, at which information is transferred from one neuron to the next by means of chemical messenger substances called neurotransmitters. In general, neurons can be divided into two classes: excitatory and inhibitory. The nervous system has three main functions: sensory input, integration of data and motor output ***(Mathias et al., 2005)***.

The most rostral part of the nervous system (cerebrum, or forebrain) is the most phylogenetically advanced and is responsible for the most complex functions. More caudally, the brain stem, and spinal cord serve less advanced, but essential functions. The brain, which accounts for about 2% of the body's weight, contains many billions of neurons and glial cells. The information is processed and encoded in a sequence of electrical or chemical steps that occur, in most cases, very rapidly in milliseconds. Nerve cells serving a common function, often with a common target, are frequently grouped together into nuclei. ***(Stephen, 2013)***

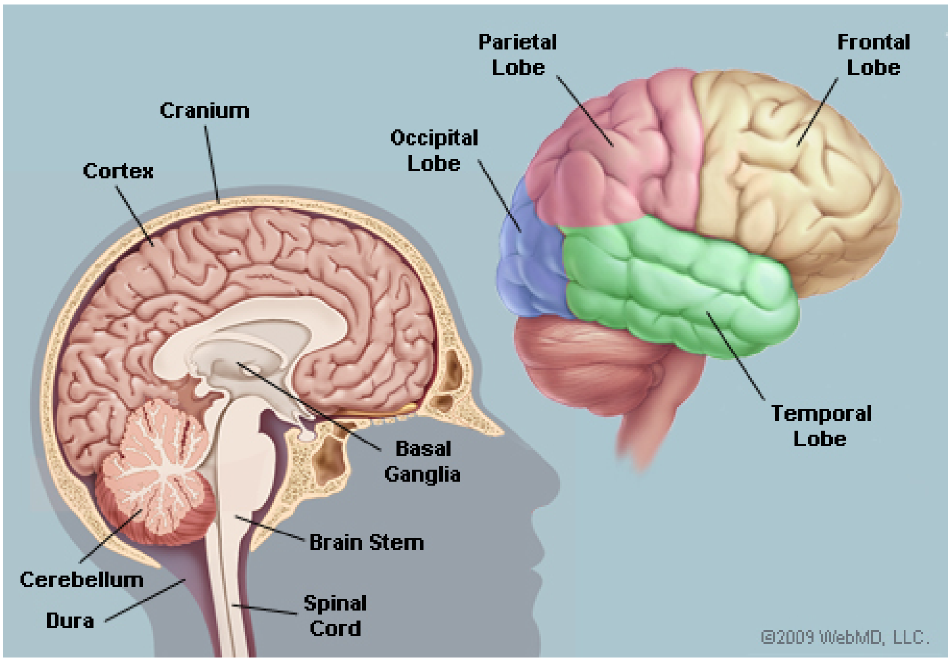

Figure (1): Gross Anatomy of Human Brain Lateral, and Sagittal view ***(2014 WebMD).***

Structure and function of neurons

Neurons are highly specialized for the processing and transmission of cellular signals. The soma (cell body) is the central part of the neuron. It contains the nucleus of the cell, and therefore is where most protein synthesis occurs. The receptive structures of a nerve cell, called dendrites, are branched processes attached to the cell body. The forward conducting structure is the axon, at its distal end, the axon splits into a number of terminal branches, each of which ends in a so-called terminal bouton that makes contact with the next neuron. The neurotransmitters, or the enzymes catalyzing their biosynthesis, are synthesized in the perikaryon (soma) and then carried down axonal microtubules to the end of the axon in a process known as axoplasmic transport. The neurotransmitter molecules are stored in synaptic vesicles inside the terminal boutons (Figure 2) ***(Mathias et al., 2005).***

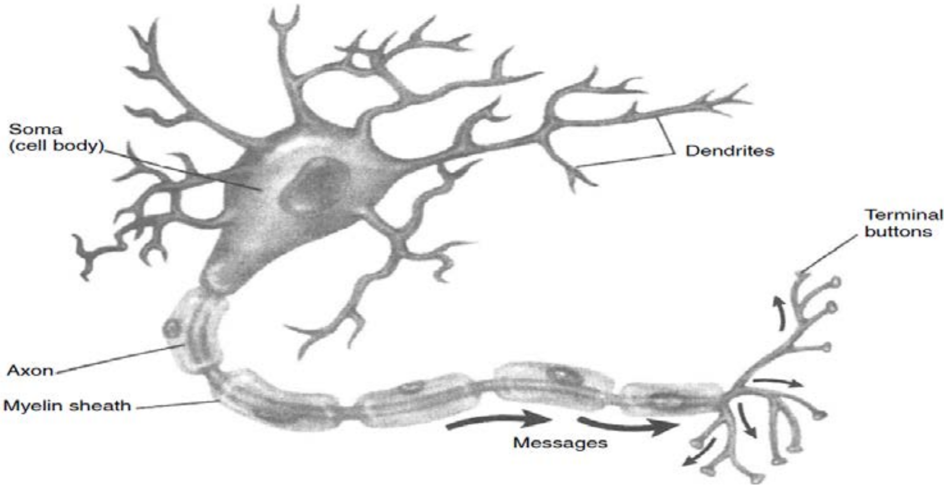

Figure (2): Structure of a neuron ***(Carlson, 1994).***

The presynaptic and postsynaptic membranes are separated by the synaptic cleft. The excitatory impulse arriving at the axon terminal depolarizes the presynaptic membrane, causing voltage-dependent calcium channels to open. The neurotransmitter molecules within the vesicles are thereby released into the synaptic cleft binds to specific receptors on the postsynaptic membrane causing ion channels to open, that cause either a depolarization or a hyperpolarization of the postsynaptic membrane, either an excitatory postsynaptic potential or an inhibitory postsynaptic potential. The commonest excitatory neurotransmitter in the CNS is glutamate, while the commonest inhibitory neurotransmitter is γ-aminobutyric acid (GABA). Other important neurotransmitters include dopamine, serotonin, and various neuropeptides are also identified ***(Mathias et al., 2005)***

Gross Anatomy of the Brain

i) Cerebrum

The cerebrum is the largest component of the brain. It is divided into right and left hemispheres separated by the longitudinal cerebral fissure. The corpus callosum is the collection of white matter fibers that joins these hemispheres. Each of the cerebral hemispheres is further divided into 4 lobes: the frontal lobe, the parietal lobe, the temporal lobe, and the occipital lobe. The frontal lobe is distinguished from the parietal lobe posteriorly by the central sulcus. The frontal lobe and parietal lobes are divided inferiorly from the temporal lobe by the lateral sulcus. The parietal lobe is distinguished from the occipital lobe by the parieto-occipital sulcus on the medial surface (Figure 3) ***(Anand et al., 2013).***

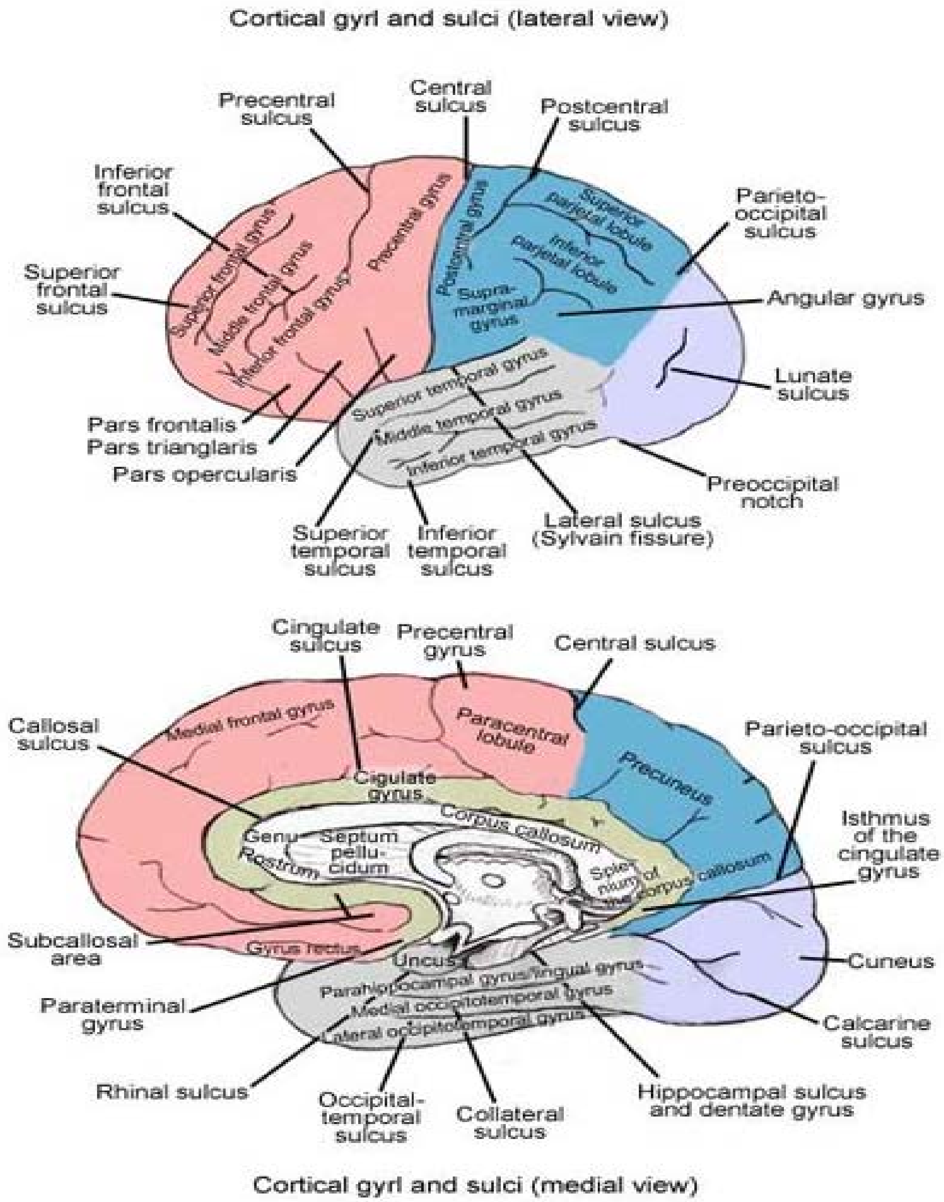

Figure (3): Cortical gyri and sulci lateral and medial views.

a) **Frontal lobe**: located under the frontal bone; contains the primary motor cortex (precentral gyrus) and is involved in complex learning.

b) **Parietal lobe** located under parietal bone; contains the primary sensory cortex (postcentral gyrus) involved in language acquisition.

c) **Temporal lobe**: located under temporal bone; processes information associated with hearing and equilibrium.

d) **Occipital lobe**: located under occipital bone; processes visual information and is related to our understanding of the written word.

e) **Insula**: Region of the cerebrum deep within the lateral sulcus; processes information associated with hearing and equilibrium.

(Marieb and Hoehn, 2012)

ii) Basal Ganglia

The basal ganglia are a part of the motor system. The principal nuclei of the basal ganglia are the caudate nucleus, the putamen, and the globus pallidus. These nuclei are connected to each other, and to the motor cortex, in complex regulatory circuits. They exert both excitatory and inhibitory effects on the motor cortex. They play an important role in the initiation and modulation of movement and in the control of muscle tone. Lesions of the basal ganglia can produce either an excess or a deficiency of movement-related impulses, and/or pathological alterations of muscle tone ***(Mathias et al., 2005).***

iii) Diencephalon

It has four components: the thalamus, epithalamus, subthalamus, and hypothalamus. The thalamus is found on both sides of the third ventricle and consists of numerous nuclei with different functions. It is the relay station for most of the afferent pathways that ascend to the cerebral cortex. Moreover, the thalamus has extensive connections with the basal ganglia, brainstem, cerebellum, and motor cortical areas of the cerebrum and is thus a major component of the motor regulatory system. The epithalamus is mainly composed of the epiphysis (pineal body) and the habenular nuclei; it plays a role in the regulation of circadian rhythms. The hypothalamus, which coordinates vital bodily functions such as respiration, circulation, water balance, temperature, and nutritional intake. It also influences the activity of the endocrine glands by way of the hypothalamic pituitary axis ***(Mathias et al., 2005).***

iv) Brain stem and Cranial Nerves

The brain stem is grossly subdivided into the medulla oblongata, pons, and midbrain. Ten of the 12 pairs of cranial nerves (CN III-XII) exit from the brain stem and are primarily responsible for the innervation of the head and neck (table 1). The brain stem also contains many nuclei, the red nucleus and substantia nigra of the midbrain, the pontine nuclei, and the olivary nuclei of the medulla, all of which play an important role in motor regulatory circuits; and the nuclei of the quadrigeminal plate of the midbrain, which are important relay stations in the visual and auditory pathways. Furthermore, practically the entire brainstem is permeated by a diffuse network of more or less “densely packed” neurons (the reticular formation), which contains the essential autonomic regulatory centers for many vital bodily functions, including cardiac activity, circulation, and respiration. The reticular formation also sends activating impulses to the cerebral cortex that are necessary for the maintenance of consciousness ***(Mathias et al., 2005).***

Table (1): Cranial Nerves

Name	Function
I The olfactory nerve	Relays information from the nerves of the olfactory epithelium to mesial temporal lobe and frontal lobe structures
II Optic Nerve	Relays visual information from the retina; the right and left optic nerves then join at the optic chiasm, where they give rise to the optic tracts, which convey visual information to the thalamus and brainstem and, ultimately, the visual cortex
III Oculomotor Nerve	Involved in the control of eye movements through its innervation of the superior rectus, the medial rectus, the inferior rectus, and the inferior oblique muscles and Pupil constriction
IV Trochlear Nerve	Innervates the superior oblique muscle and is purely a motor nerve
V Trigeminal Nerve	Motor and sensory nerve and has 3 divisions, V1 (the ophthalmic division), V2 (the maxillary division), and V3 (the mandibular division); it is involved in conveying sensory information from the face and also in controlling the muscles of mastication
VI Abducent Nerve	Innervates the lateral rectus nerve, allowing lateral eye movements
VII Facial Nerve	Principally involved in innervation of the muscles of facial expression and also plays a role in tearing, salivation
VIII Vestibulocochlear Nerve	A purely sensory nerve that conveys auditory information from the cochlea to the brainstem via the cochlear branch; the vestibular branch conveys proprioceptive information about head position and movement from the inner ear to the brainstem
IX Glossopharyngeal Nerve	Is involved in taste and salivation, as well as sensation in the oropharynx; the afferent limb of the gag reflex is mediated by the glossopharyngeal nerve
X Vagus Nerve	Conveys visceral sensation to the brainstem and also controls some visceral functions, such as heart rate and gastrointestinal motility
XI Spinal Accessory Nerve	Head turning (trapezius and sternomastoid muscles)
XII Hypoglossal Nerve	Tongue movements

(Anand et al., 2013)

v) Cerebellum:

The cerebellum is the largest part of the hind-brain and occupies most of the posterior cranial fossa. It is made up of two lateral cerebellar hemispheres and a median vermis. It is connected to the brainstem by the three cerebellar peduncles. Functionally, the cerebellum is divided into three components: Vestibulocerebellum and its function is to regulate balance. The spinocerebellum and its function is to controls stance and gait. The cerebrocerebellum is responsible for the smooth and precise execution of all finely controlled movements. The cerebellum is principally concerned with balance and the regulation of posture, muscle tone and muscular co-ordination; consequently, cerebellar lesions result in some disturbance of one or more of these motor functions in the form of an unsteady gait, hypotonia, tremor, nystagmus and dysarthria ***(Harold, 2006).***

vi) Meninges:

Three membranes envelop the brain: the dura, the arachnoid, and the pia. The dura, the outer membrane, is separated from the thin arachnoid by a potential compartment, the subdural space, which normally contains only a few drops of Cerebrospinal fluid (CSF). An extensive subarachnoid space containing CSF and the major arteries separates the arachnoid from the pia, which completely invests the brain. The pia, together with a narrow extension of the subarachnoid space, accompanies the vessels deep into the brain tissue; this space is called the perivascular space, or Virchow-Robin's space (Figure 4) ***(Stephen, 2013).***

a) Dura Matter:

The dura is a dense membrane which, within the cranium, is made up of two layers. The outer layer is intimately adherent to the skull; the inner layer is united to the outer layer except where separated by the great dural venous sinuses and where it projects to form four sheets 1) the falx cerebri; 2) the falx cerebelli; 3) the tentorium cerebelli; and 4) the diaphragma sellae ***(Harold, 2006).***

b) Arachnoid:

The arachnoid is a delicate membrane separated from the dura by the potential subdural space. It projects only into the longitudinal fissure and the stem of the lateral fissure. The arachnoid and the pia mater are connected to each other across this space by delicate strands of connective tissue ***(Harold, 2006).***

c) Pia Mater:

The pia mater consists of thin layers of mesodermal cells resembling endothelium and is closely moulded to the outline of the brain; it dips down into the cerebral sulci leaving the subarachnoid space between it and the arachnoid. This space is broken up by trabeculae of fine fibrous strands and contains the CSF ***(Harold, 2006).***

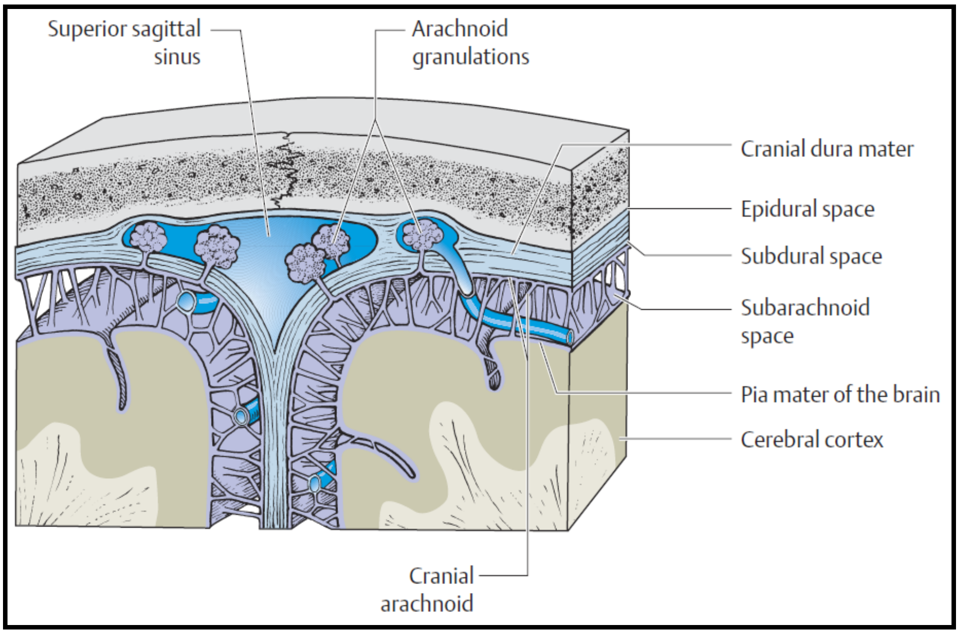

Figure (4): Meningeal covering of the brain
(Topical Diagnosis in Neurology, 2005)

vii) Cerebrospinal fluid and ventricular system:

The brain is bathed in cerebrospinal fluid (CSF), continuously produced and absorbed, CSF is produced at a rate of about 450 mL/day, and normally is clear and colorless, containing only a few cells and relatively little protein (Table 2). The CSF is actively secreted by the choroid plexus of the lateral, third and fourth ventricles. It flows through the foramina of Luschka and Magendie into the subarachnoid space, circulates around the brain, and flows down into the spinal subarachnoid space. CSF is resorbed intracranially and along the spinal cord. The blood