INTRODUCTION

Although complications are a significant risk factor following any surgical procedure, there are particular neurological complications often related to cardiac surgery, including embolic stroke and transient ischemic attacks that are associated with high postoperative morbidity and mortality ***(Baranowska et al., 2012).***

As with other types of surgery, the development of these neurologic complications may be linked to a patient's preexisting comorbid condition, such as peripheral vascular disease, congestive heart failure, or a previous history of myocardial infarction ***(Wanamaker et al., 2012).***

Patient at risk for embolic events may be screened preoperatively using ultrasonography to determine the presence of aortic plaque near the sites for cannulation, cross-clamping, and saphenous vein grafting to avoid embolization. However the etiology of serious neurologic complications also may be related to a second factor: hypoperfusion occurring within the perioperative period. This factor is of particular concern during cardiopulmonary bypass (CPB) when there is non pulsatile blood flow and typically lower mean arterial blood pressure ***(Wanamaker et al., 2012).***

Neurological complications are more common among patients undergoing surgery with (CPB), especially complex surgery, involving aortic valve replacement, surgery of multiple valves, or involvement of aortic surgery. Various causative

mechanisms have been postulated for neurological injury after CPB including, embolization of gaseous and particulate matter, cerebral hypoperfusion, and inflammatory response to CPB. All of these mechanisms cause an imbalance between oxygen delivery and oxygen consumption in the brain ***(Slater et al., 2009).***

Studies have shown an increased incidence of adverse perioperative outcomes including neuropsychological dysfunction ***(Yao et al., 2004)***, prolonged hospital length of stay and major organ morbidity and mortality, when patient experience cerebral oxygen desaturation regardless of the type of surgery or when the procedure is performed on-pump or off-pump ***(Fischer et al., 2011).***

Neuromonitoring during cardiac surgery might help to prevent injurious events or to detect them in the early hours in order to employ strategies to minimize secondary cerebral damage. At present experience with neurophysiologic techniques include the ability to measure cerebral blood flow velocity, emboli and regional cerebral venous oxygen saturation by transcranial Doppler ultrasound, and by near-infrared spectroscopy, respectively. Continuous monitoring of these variables along with systemic hemodynamics will provide a better understanding of mechanisms of brain and other organ injury during CPB. Neuroprotective interventions based on multimodality neurologic monitoring would ideally eliminate postoperative complications and improvepatient outcome ***(Marino et al., 2012).***

AIM OF THE STUDY

The aim of this study is to determine neurological monitors during cardio pulmonary bypass to prevent injurious events or to detect them in the early hours in order to employ strategies to minimize secondary cerebral damage.

ANATOMY OF THE CENTRAL NERVOUS SYSTEM

The nervous system is organized into two parts: the central nervous system(CNS), which consists of the brain and the spinal cord, and the peripheral nervous system, which connects the central nervous system to the rest of the body ***(Singh, 2014).***

The central nervous system is composed of large numbers of nerve cells called neurons. The long processes of a nerve cell are called axons or nerve fibers. The interior of the central nervous system is organized into gray matter consists of nerve cells and white matter consists of nerve fibers. The billions of neurons in the brain are connected to neurons throughout the body by trillions of synapses ***(Brodal, 2010).***

Brain:

The brain contains more than 90% of the body's neurons. The brain has been divided into 3 different areas: the hindbrain, the midbrain, and the forebrain.

The hindbrain is made up of the cerebellum, the pons, and the medulla. The medulla is a narrow structure nearest the spinal cord; it is the point at which many of the nerves from the left part of the body cross to the right side of the brain and vice versa. The medulla controls such functions as breathing, heart

rate, and blood pressure. The pons, located just above the medulla, connects the top of the brain to the cerebellum. Chemicals produced in the pons help maintain our sleep-wake cycle ***(Brazis et al., 2011).***

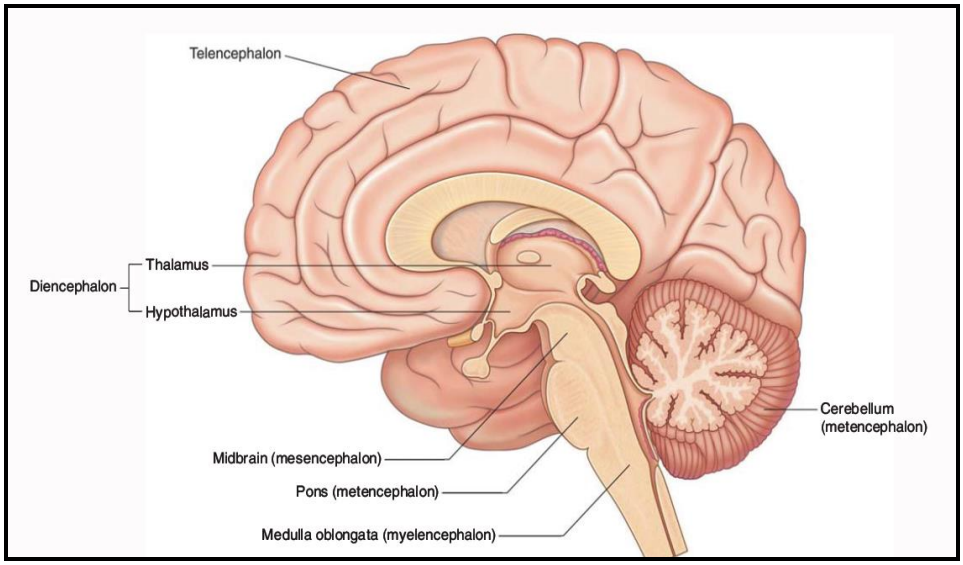

Figure (1): Sagittal section of the brain ***(Gray, 2014)***

The cerebellum lies within the posterior cranial fossa of the skull, posterior to the pons and the medulla oblongata. It consists of 2 laterally placed hemispheres connected by a median portion, the vermis. The cerebellum handles certain reflexes, especially those that have to do with balance. It also coordinates the body's actions ***(Blumenfeld, 2011).***

The midbrain lies between the hindbrain and forebrain and is crucial for hearing and sight. The forebrain is supported by the brain stem and buds out above it, drooping somewhat to fit inside the skull. It consists of the thalamus, the hypothalamus, and the cerebral cortex ***(Snell, 2009).***

The cerebral hemispheres, located above the thalamus and hypothalamus, take up most of the room inside the skull. The outer covering of the cerebral hemispheres is known as the cerebral cortex. Each cerebral hemisphere is divided into 4 lobes, delineated by deep fissures on the surface of the brain: The occipital lobe, the temporal lobe, the parietal lobe, and the frontal lobe. These lobes are both physically and functionally distinct. Each lobe contains areas for specific motor sensory function as well as association areas ***(Snell, 2009).***

The brain lies in the cranial cavity and is continuous with the spinal cord through the foramen magnum. It is surrounded by 3 meninges: the dura mater, the arachnoid mater, and the pia mater; these are continuous with the corresponding meninges of the spinal cord. The cerebrospinal fluid surrounds the brain in the subarachnoid space ***(Snell, 2009).***

Spinal cord:

The spinal cord is the most important content of the vertebral canal and in adults, it occupies only the upper two-thirds of the vertebral canal. It begins as a downward extension of medulla oblongata at the level of the upper border of the first cervical vertebra (C1) and extends down to the level of the lower border of the first lumbar vertebra (L1). The lowest part of the spinal cord is conical and is called the conus medullaris. The conus is continuous, below, with a fibrous cord called the filum terminale, which is a prolongation of piamater and is

attached to the posterior surface of the coccyx. The spinal cord is surrounded by 3 meninges: the dura mater, the arachnoid mater, and the pia mater. Further protection is provided by the cerebrospinal fluid, which surrounds the spinal cord in the subarachnoid space ***(Singh, 2014).***

The length of the cord varies from 42 to 45 cm. The spinal cord gives attachment on either side to 31 pairs of spinal nerves: 8 cervical, 12 thoracic, 5 lumbar, 5 sacral, and 1 coccygeal. Each spinal nerve arises by two roots, anterior motor root and posterior sensory root. In the intervertebral foramen, anterior and posterior spinal nerve roots unite to form the mixed spinal nerve trunk ***(Singh, 2014).***

Unlike the brain, the spinal cord is composed of an inner core of gray matter, which is surrounded by an outer covering of white matter. The gray matter is seen on cross-section as an H-shaped pillar with anterior and posterior gray columns, or horns, united by a thin gray commissure containing the small central canal ***(Biller et al., 2011).***

The brain ventricular system:

The ventricles of the brain are a communicating network of cavities filled with cerebrospinal fluid (CSF) and located within the brain parenchyma. The ventricular system is composed of:

Lateral ventricles:

The largest cavities of the ventricular system. Each lateral ventricle is divided into a central portion, formed by the body and atrium (or trigone), and 3 lateral extensions or horns of the ventricles. The central portion or the body of the ventricle is located within the parietal lobe. The interventricular

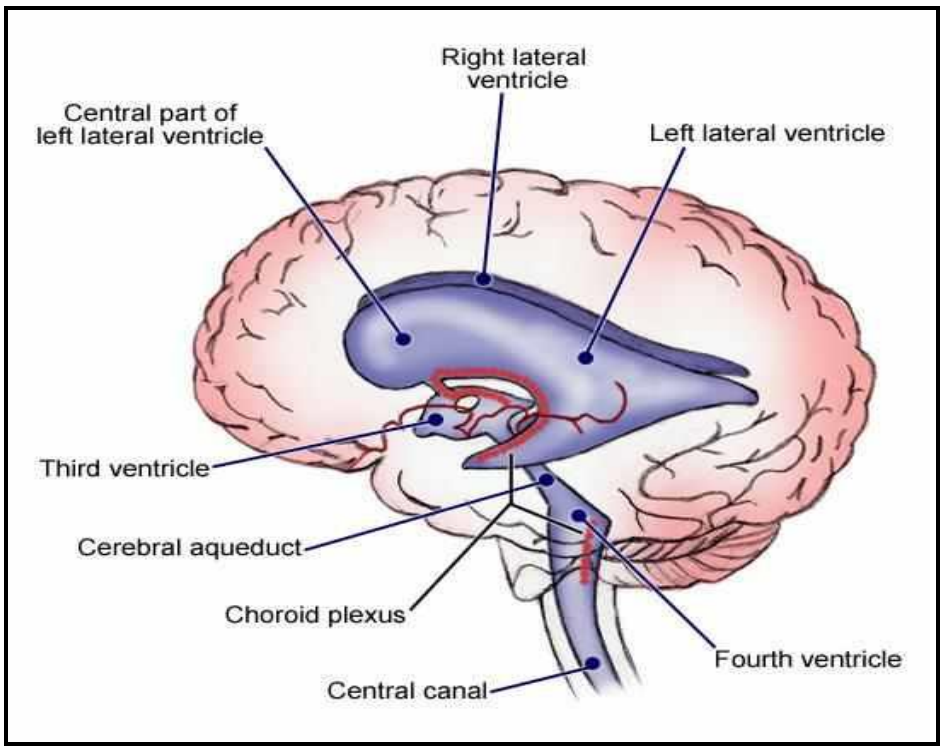

Figure (2): The ventricular system of the human brain ***(Waxman, 2000).***

foramen is located at the anterior margin of the body. The 2 interventricular foramens (or foramina of Monro) connect the lateral ventricles with the third ventricle. The body of the lateral ventricle is connected with the occipital and temporal horns by

a wide area named the atrium. The anterior or frontal horn is located anterior to the interventricular foramen. The inferior or temporal horn is located within the temporal lobe ***(Kapoor et al., 2008).***

Capillaries of the choroid arteries from the pia mater project into the ventricular cavity, forming the choroid plexus of the lateral ventricle.The anterior choroidal arteries (branch of internal carotid artery) and lateral posterior choroidal arteries (branch of the posterior cerebral artery) form the choroid plexus. Venous supply from the choroidal veins drain into the cerebral veins ***(Redzic and Segal, 2004).***

Third ventricle:

The third ventricle is the narrow vertical cavity of the diencephalon. A thin tela choroidea supplied by the medial posterior choroidal arteries (branch of posterior cerebral artery) is formed in the roof of the third ventricle ***(Brown et al., 2004).***

Fourth ventricle:

The fourth ventricle is connected to the third ventricle by a narrow cerebral aqueduct. The fourth ventricle is a diamond-shaped cavity located posterior to the pons and upper medulla oblongata and antero-inferior to the cerebellum ***(Kapoor et al., 2008).***

Inferiorly, it extends into the central canal of medulla. The fourth ventricle communicates with the subarachnoid space through the lateral foramen of Luschka, located near the flocculus of the cerebellum, and through the median foramen of Magendie, located in the roof of the ventricle ***(Waxman, 2000).***

Cerebrospinal fluid:

CSF is a clear, watery fluid that fills the ventricles of the brain and the subarachnoid space around the brain and spinal cord. CSF is produced primarily by the choroid plexus of the ventricles (up to 70% of the volume), most of it being formed by the choroid plexus of the lateral ventricles. The rest of the CSF production is the result of transependymal flow from the brain to the ventricles ***(Fenichel, 2005).***

Blood Supply of the CNS:

The arterial blood supply to the brain is composed of paired right and left internal carotid arteries, which give rise to the anterior circulation, and paired right and left vertebral arteries, which give rise to the posterior circulation. The connection of the two vertebral arteries forms the basilar artery. The internal carotid arteries and the basilar artery connect to form a vascular loop called the circle of Willis that permits collateral circulation between both the right and left and the anterior and posterior perfusing arteries. Three paired arteries that originate from the circle of Willis perfuse the brain:

anterior, middle, and posterior cerebral arteries. The posterior communicating arteries and the anterior communicating artery complete the loop. The anterior and the posterior circulations contribute equally to the circle of Willis. ***(Duvernoy and Risold, 2007)***

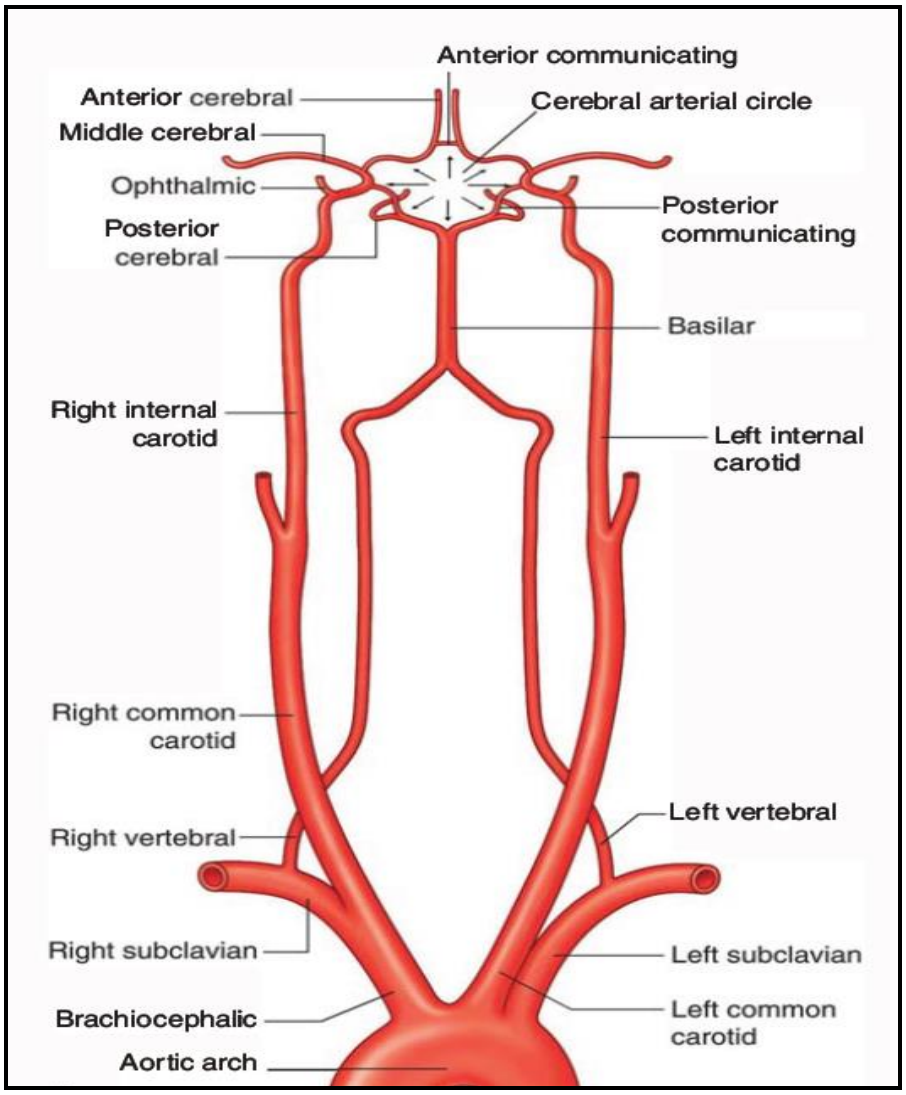

Figure (3): Major arteries supplying the brain ***(Singh, 2014).***

Venous drainage of the brain:

Three sets of veins drain blood from the brain. The superficial cortical veins are within the pia mater on the brain surface. Deep cortical veins drain the deeper structures of the brain. These veins drain into dural sinuses, of which the superior and inferior sagittal sinuses and the straight, transverse and sigmoid sinuses are the major dural sinuses. These ultimately drain into the right and left internal jugular veins ***(Miller, 2015).***

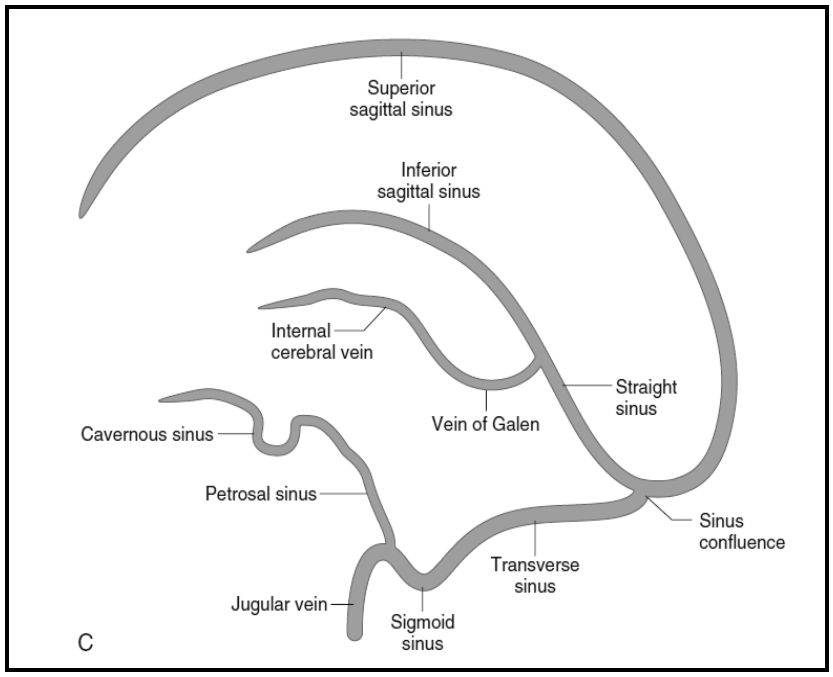

Figure (4): Venous drainage of the brain ***(Miller, 2015).***

PHYSIOLOGY OF CENTRAL NERVOUS SYSTEM

The nervous system has three main functions: sensory input, integration of data and motor output. Sensory input is when the body gathers information or data, by way of neurons, glia and synapses. The nervous system is composed of excitable nerve cells (neurons) and synapses that form between the neurons and connect them to centers throughout the body or to other neurons. These nerves conduct impulses from sensory receptors to the brain and spinal cord. The data is then processed in the brain and impulses are then conducted from the brain and spinal cord to muscles and glands, which is called motor output ***(Spruston, 2008).***

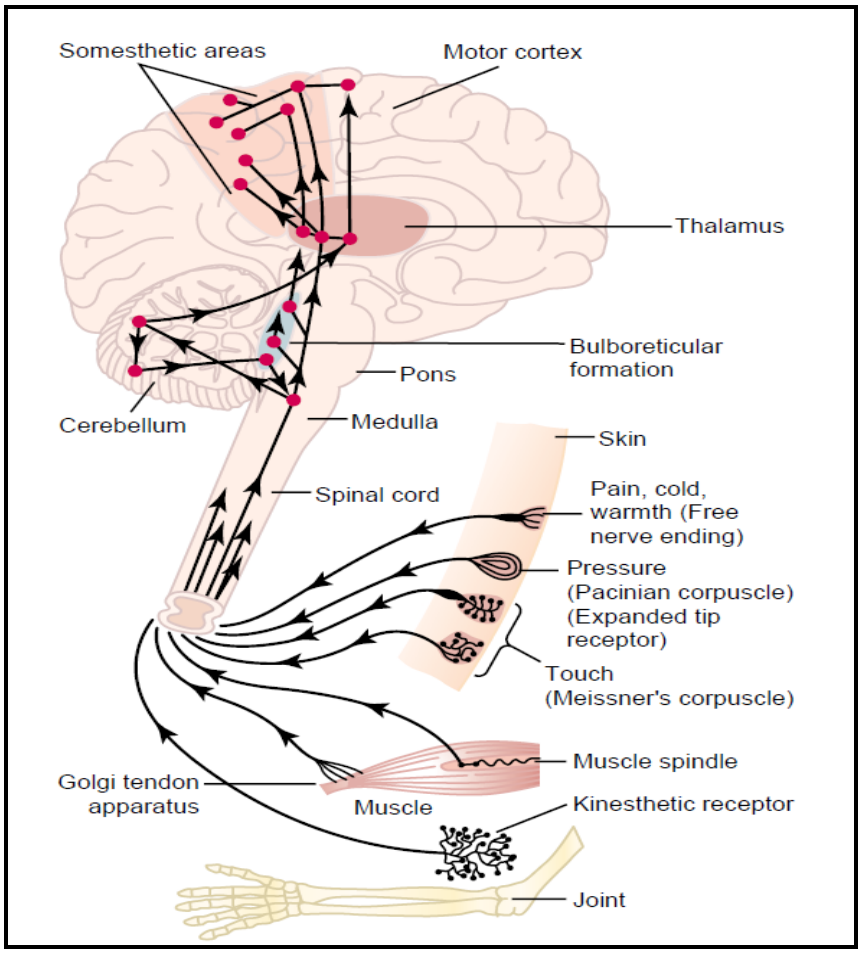

Figure (5): Somatosensory axis of the nervous system ***(Guyton and Hall, 2006)***

Regulation of the Cerebral Blood Flow:

The adult human brain weighs approximately 1350 g and therefore represents approximately 2% of total body weight. However, it receives 12% to 15% of cardiac output. This high flow rate is a reflection of the brain's high metabolic rate. At rest, the brain consumes oxygen at an average rate of approximately 3.5 mL of oxygen per 100 g of brain tissue per

minute. Whole-brain oxygen consumption (50 mL/min) represents approximately 20% of total body oxygen utilization. Under normal circumstances, cerebral blood flow (CBF) is approximately 50 mL/100 g/min. Approximately 60% of the brain's energy consumption supports electrophysiologic function. The remainder of the energy consumed by the brain is involved in cellular homeostatic activities ***(Antunes-Rodrigues et al., 2004).***

The brain's metabolic requirements must be met by adequate delivery of oxygen and glucose. However, the space constraints imposed by the noncompliant cranium and meninges require that blood flow not be excessive. Not surprisingly, elaborate mechanisms regulate CBF. These mechanisms, include chemical, myogenic, and neurogenic factors ***(Antunes-Rodrigues et al., 2004).***

Chemical Regulation:

Several factors, including changes in cerebral metabolic rate (CMR), arterial partial pressure of carbon dioxide ($PaCO_2$), and arterial partial pressure of oxygen (PaO_2), cause alterations in the cerebral biochemical environment that result in adjustments in CBF. Increased neuronal activity results in increased local brain metabolism, and this increase in the CMR is associated with a proportional change in CBF that is referred to as flow-metabolism coupling. Although the precise mechanisms that mediate flow-metabolism coupling have not