Introduction

Over the last decade there has been a trend towards shorter, less invasive surgical procedures within every surgical discipline.

Technological advances in imaging, computing, optics and miniaturization have encouraged the increasing trend to applying minimally invasive surgical techniques to a variety of brain surgical procedures ***(Fabregas and Craen, 2002).***

Minimally invasive brain surgery is the fulfillment of a long-felt need to develop surgical techniques with minimum potential for damage to the normal brain and a sequel to various technological innovations ***(Ramani, 2003).***

The procedure is minimally invasive because only a single burr hole is required on the skull. At the level of the cerebral cortex, entry into the ventricles is through the frontal horn on the nondominant side ***(Ramani, 2003).***

The potential benefit of minimally invasive brain surgery results from enhanced patient safety, shorter hospital stay, reduced invasiveness, and lower postoperative morbidity compared with open surgical procedures ***(Schubert et al., 2006).***

New surgical procedures demand new anesthetic techniques, concerning the control of intracranial pressure and early recovery from anesthesia with minimal residual effects. In addition to this, in the intraoperative period all measures should be taken to ensure that patient does not move, because any movement with the endoscope in place can cause misdirection of the scope and avoidable neurological damage ***(Schubert et al., 2006).***

This essay discusses the wide application of brain surgery and the implications of anesthesia, focusing on the specific anesthetic considerations for brain endoscopy, stereotactic procedures and the Gamma knife surgery.

Aim of the Work

The aim of the work is to review the anatomy and pathophysiology of the brain and the recent trends in the anesthesia for minimally invasive brain surgery.

Brain Anatomy

Description

There are three main parts of the brain:

Forebrain:

Telencephalon:

Consists of the two cerebral hemispheres separated by a longitudinal fissure. The cortex of each hemisphere is made up of gyri and sulci and is separated into lobes. Four major lobes are commonly recognized frontal, parietal, occipital and temporal ***(Erdmann, 2001).***

Diencephalon:

Lies between the cerebral hemispheres and midbrain. It contains the thalamus and the hypothalamus ***(Kent and Rhees, 2001).***

Midbrain:

Connects the forebrain to the hindbrain. The cavity of the midbrain forms a narrow canal (the cerebral aqueduct) that conducts Cerebrospinal Fluid (CSF) from the lateral and 3rd ventricle to the 4th ventricle.

Hindbrain:

Consists of the pons, the medulla oblongata (which exits the cranial cavity through the foremen magnum) and the cerebellum ***(Monkhouse, 2001).***

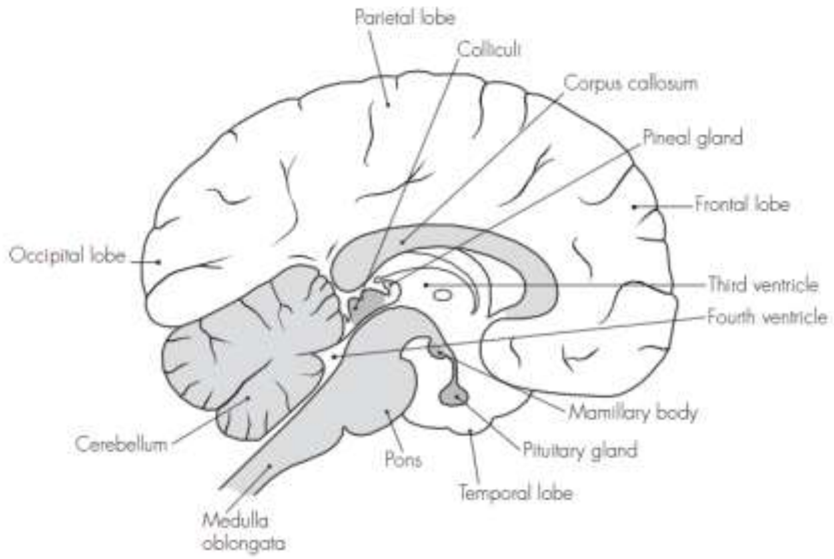

Figure 1: Anatomy of the brain ***(Erdmann, 2001).***

The pons: the part of the brainstem between the midbrain rostrally and the medulla oblongata caudally, lies in the anterior part of the posterior cranial fossa the cavity in the pons forms the 4th ventricle.

The medulla oblongata (medulla): the caudal part of brainstem that is continuous with the spinal cord lies in the posterior cranial fossa. The cavity of the medulla forms the inferior part of the 4th ventricle which leads to, and ends as the central canal of the spinal cord ***(Moore and Agur, 2006).***

Cerebellum: It is the large brain mass that consists of two hemispheres joined medially by a relatively narrow vermis, sits in the posterior cranial fossa of the skull beneath the tentorium cerebelli, and is separated from the medulla and pons by the fourth ventricle. The cerebellar cortex has many curved transverse fissures in the form of narrow infoldings called folia ***(Moore and Agur, 2006).***

Observation of the superior surface shows two deep transverse fissures, the primary and the posterior superior fissures Viewed from the ventral surface, the cerebellum is divided approximately into superior and inferior halves by the horizontal fissure. Three pairs of Cerebellar peduncles connect the cerebellum to the three lower brain segments. The inferior, middle, and superior cerebellar peduncles connect it to the medulla, pons, and midbrain, respectively.

The superior vermis lies between the hemispheres as a longitudinal ridge; it is more clearly differentiated visually from the hemispheres on the ventral surface, where it is divided by fissures into the nodule, uvula, and pyramid ***(Ben and Adam, 2000).***

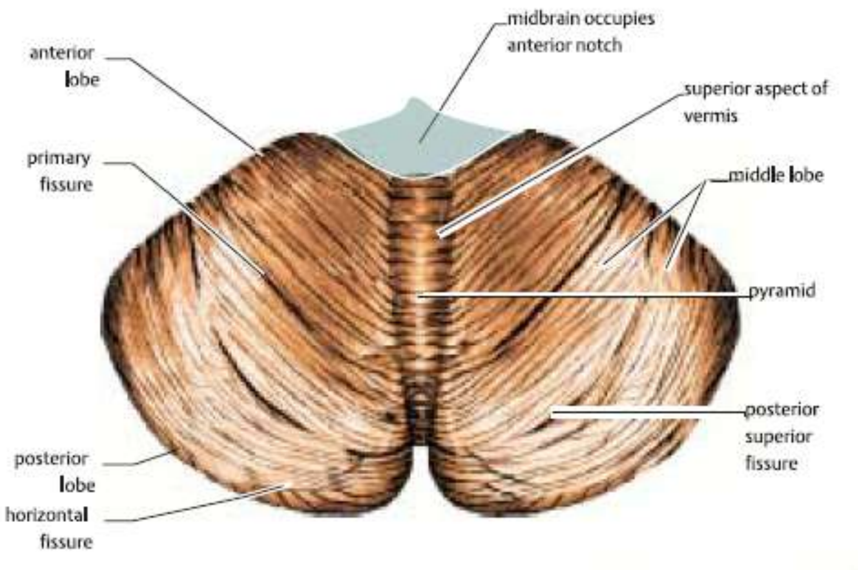

Figure 2: Dorsal aspect of cerebellum ***(Ben and Adam, 2000).***

Meninges:

There are three connective tissue membranes that surround the spinal cord and the brain.

They consist of the dura mater (outermost), arachnoid, and pia mater (innermost).

(1) The dura mater:

It is dense, fibrous, double membrane which closely covers the surface of the brain and spinal cord.

It separates into two layers, the outer (endosteal) layer strongly adherent to the skull bones and terminates at the foramen magnum, where it merges with the periosteum enclosing the skull, and is thereafter represented by the periosteal lining of the vertebral canal.

The inner (meningeal) layer made up of dense fibrous tissue and continuous with the dura which surrounds the spinal cord.

The dural sac usually extends to the level of the 2nd segment of the sacrum; occasionally it ends as high as L5, at other times it extends to S3.

The major artery supplying the dura mater is the middle meningeal artery, which may be damaged in a head injury and skull fracture, leading to the formation of an extradural hematoma ***(Ellis et al., 2004).***

(2) The arachnoid mater*:*

It is a relatively fragile, impermeable layer that covers the spinal cord, the brain and spinal nerve roots, and is separated from the pia by the wide subarachnoid space, which is filled with cerebrospinal fluid, it is continuous with the cerebral arachnoid, which loosely invests the brain, and which dips into the longitudinal fissure between the cerebral hemispheres.

Cortical veins from the surface of the brain pass through the arachnoid mater to reach dural venous sinuses and may be damaged by relatively minor trauma leading to the formation of a subdural hematoma ***(Aitkenhead et al., 2007).***

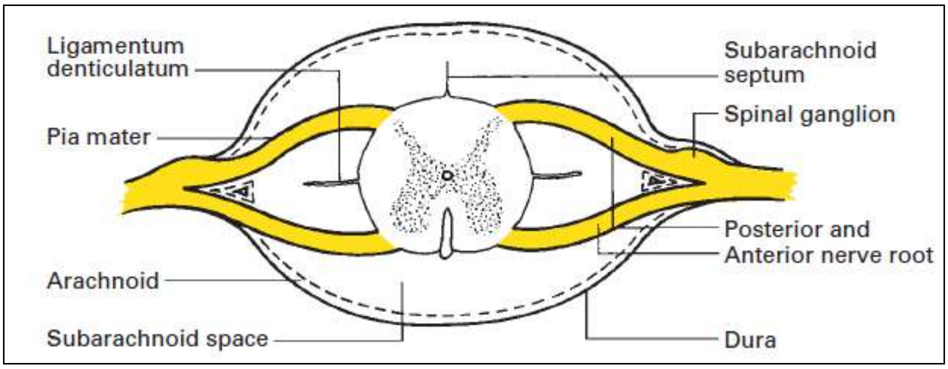

Figure 3: The Meninges in Transverse Section ***(Ellis et al., 2004).***

(3) The pia mater:

It is the innermost of the three membranes. It is a highly vascularized membrane closely adherent to the surface of the brain and follows the contours of the gyri and sulci.

It is thickened anteriorly into the linea splendens along the length of the anterior median fissure and has lateral strands for attachments to the dura forming the ligamentum denticulatum which is a series of triangular fibrous strands attached at their apices to the dural sheath; they are 21 in number, and lie between the spinal nerves down to the gap between the 12th thoracic and 1st lumbar root. The lowermost denticulation is bifid and is crossed by the 1st lumbar nerve root, posteriorly it attaches to the dura by an incomplete sheet of pia forming posterior subarachnoid septum. Inferiorly, the pia is continued downwards as the filum terminal, which pierces the lower end of the dural sac and then continues to the coccyx with a covering sheath of dura ***(Ellis et al., 2004).***

Meningeal spaces:

1. **Extradural (epidural) space:** (Figure 4) separates the dura mater from the periosteum. It extends from the foramen magnum to the sacral hiatus. The space is roughly triangular in cross-section, with a small anterior and two larger posterolateral compartments. The space also extends a short distance laterally through the spinal foramina (as the nerve roots exit).

   The distance from the posterior epidural space border to the dural sac varies from ~6 mm in the lumbar region to only 1 mm in the cervical region. The epidural space is found variably 3–5 cm beneath the skin (range 2–7 cm)

The posterior aspect of the space is limited by the laminae and overlying ligamentum flavum, at the sides by the pedicles of the vertebral arches and the intervertebral spaces. The front of the space is formed by the bodies of the vertebrae, the intervertebral discs and the posterior longitudinal ligament ***(Ellis et al., 2004).***

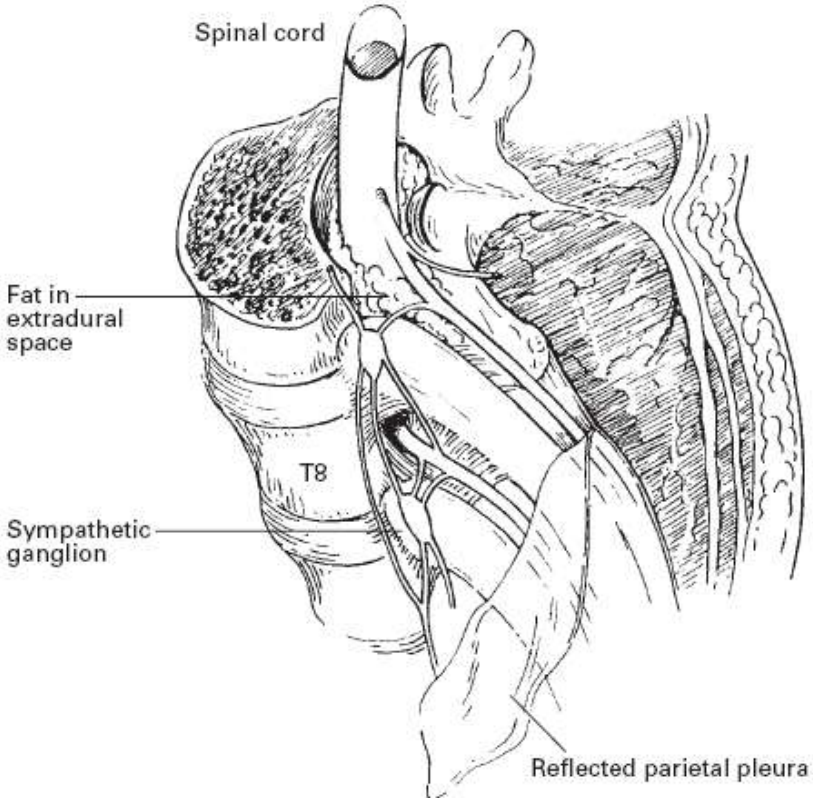

Figure 4: The epidural space ***(Ellis et al., 2004).***

2. **Subdural space:** a potential space as the arachnoid mater is closely applied to the dura (with a thin film of serous fluid in between) The subdural space within the vertebral canal

rarely enters the consciousness of the clinician, unless it is the accidental site of catheter placement during attempted epidural analgesia or anaesthesia. The subdural injection of local anaesthetic is thought to be associated with patchy anaesthesia, often unilateral and often extensive.

3. **The subarachnoid space (SAS):** contains the cerebrospinal fluid (CSF). It is traversed by incomplete trabeculae-the posterior subarachnoid septum and the ligamentum denticulatum. This space communicates with the tissue spaces around the vessels in the pia mater that accompany them as they penetrate into the cord. These continuations of the subarachnoid space have been described as breaking up into fine ramifications that surround individual nerve cells (the Virchow–Robin spaces) ***(Ellis et al., 2004).***

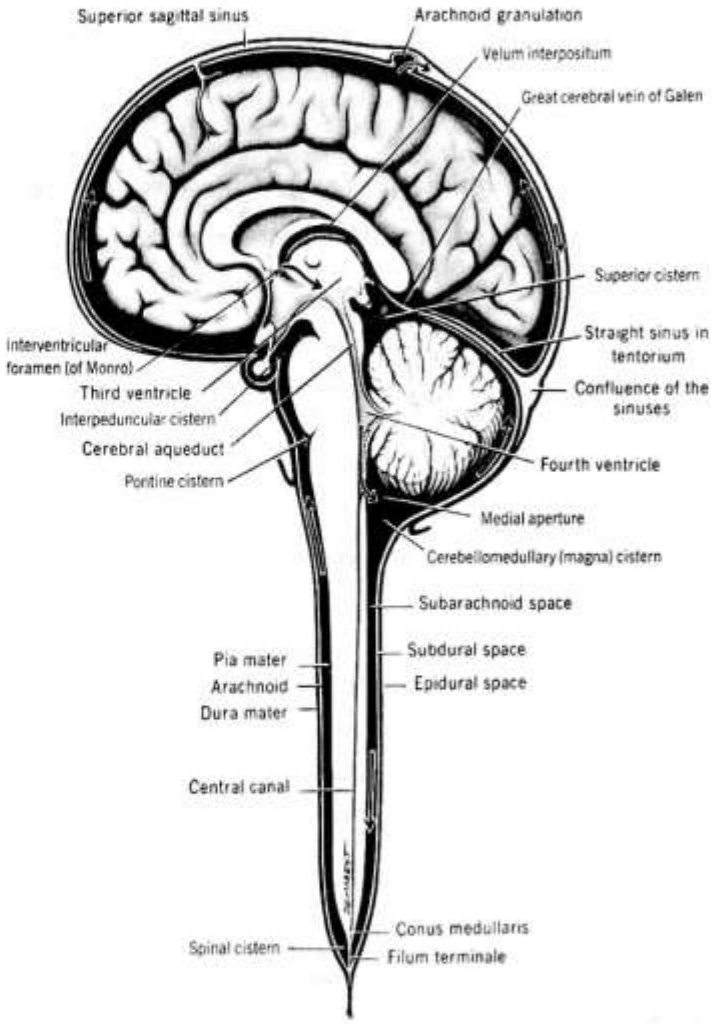

Figure 5: The subarachnoid spaces and cisterns of the brain and spinal cord ***(Fix, 2004).***

Ventricular System:

Ventricular system of the brain consists of:

1. **The two lateral ventricles; (**Figure 6, 7) which are the largest component of the system. They occupy a considerable part of the cerebral hemisphere. Each ventricle has an anterior horn, a body above and medial to the body of

the caudate nucleus, posterior horn in the occipital lobe and an inferior horn reaching down into the temporal lobe. They communicate with the third ventricle through the interventricular foramina of Monro.

2. **The 3rd ventricle;** it is a narrow midline slit like cavity between the two thalami in its upper portion and the hypothalamus in its lower part. Its floor is formed by the hypothalamus. It communicates with the 4th ventricle through the cerebral aqueduct of Sylvius.

3. **The 4th ventricle;** it is diamond shaped when viewed from above and tent-shaped as seen from the side. Its floor is formed below by the medulla and above by the pons.Its roof is formed by the cerebellum and the superior and the inferior medullary vessels. The CSF escapes from the 4th ventricle into the subarachnoid space by way of the median and lateral apertures of Magendie ad Luschka respectively and then flows over the surface of the brain and spinal cord ***(Ellis, 2002).***

The choroid plexus is a specialized structure that projects into the lateral, third, and fourth ventricles of the brain. It consists of infoldings of blood vessels of the pia mater that are covered by modified ciliated ependymal cells. It secretes the CSF. Tight junctions of the choroid plexus cells form the blood CSF barrier ***(Fix, 2004).***

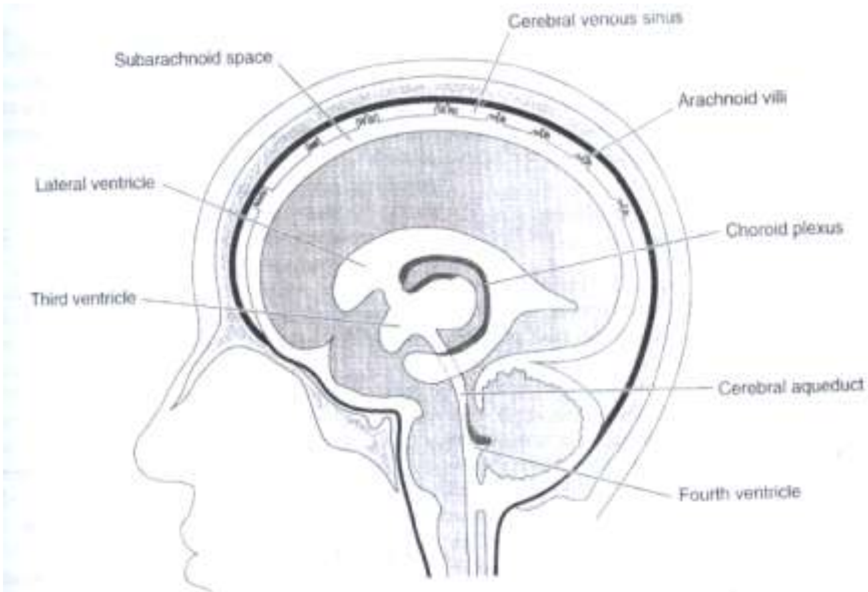

Figure 6: The ventricular system ***(Aitkenhead et al., 2007).***

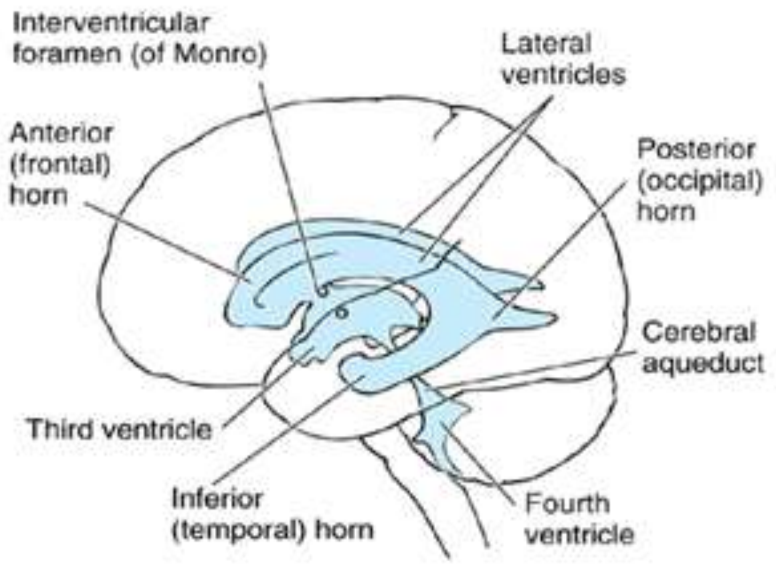

Figure 7: The ventricular system ***(Waxman and Stephen, 2003).***

Hydrocephalus:

It is dilation of the cerebral ventricles by blockage of the CSF pathways. It is characterized by excessive accumulation of CSF in the cerebral ventricles or subarachnoid space.

1. **Noncommunicating hydrocephalus** results from obstruction within the ventricles (e.g; congenital aqueductal stenosis).

2. **Communicating hydrocephalus** results from blockage within the subarachnoid space (e.g; adhesions after meningitis).

3. **Normal Pressure hydrocephalus** occurs when the CSF is not absorbed by the arachnoid villi. It may occur secondary to post traumatic meningeal hemorrhage.

4. **Hydrocephalus ex vacuo** results from a loss of cells in the caudate nucleus (e.g; Huntington's disease).

5. **Pseudotumor cerebri** (benign intracranial hypertension) results from increased resistance to CSF outflow at the arachnoid villi. It occurs in obese young women ***(Fix, 2004).***

Cerebrospinal fluid

It is a clear watery fluid, flow through the ventricles and into the subarachnoid space.