COMPARISON BETWEEN VENTRICULOSUBGALEAL SHUNT AND EXTRAVENTRICULAR DRAINAGE TO TREAT ACUTE HYDROCEPHALUS IN ADULTS AT HOSPITAL QUEEN ELIZABETH BETWEEN 2013 AND 2015: A RETROSPECTIVE STUDY

by

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LIST OF ABBREVIATIONS

cm: centimetre

CSF: cerebrospinal fluid

CT: computed tomography

CTA: computed tomography angiogram

EDH: extradural haematoma

EVD: extraventricular drainage

ETV: endoscopic third ventriculostomy

GCS: Glasgow Coma Scale

ICH: intracranial haemorrhage

ICP: intracranial pressure

IV: intravenous

IVH: intraventricular haemorrhage

LA: Local anaesthesia

mm: millimetre

MRI: magnetic resonance imaging

mRS: modified Rankin Scale

PTH: post-traumatic hydrocephalus

SAH: subarachnoid haemorrhage

SD: standard deviation

SDH: subdual haemorrhage

TB: tuberculosis

VPS: ventriculoperitoneal shunt

VSGS: ventriculosubgaleal shunt

ABSTRAK

Pengenalan

Hidrosefalus didefinisikan sebagai jumlah cecair cerebrospinal (CSF) yang tidak sesuai dalam ruang intrakranial pada tekanan yang tidak sesuai. Keputusan untuk merawat hidrosefalus adalah berdasarkan puncanya. Perubahan hemodinamik CSF disebabkan oleh keadaan seperti pendarahan subaraknoid dan ventrikal, meningitis dan teanan luar dari ketumbuhan otak mempunyai kebarangkalian untuk reda selepas rawatan; maka, lencongan sementara CSF perlu dipertimbangkan. Ventriculosubgaleal shunt (VSGS) boleh digunakan untuk lencongan sementara CSF kerana ia adalah satu kaedah yang mudah dan cepat, dan dapat mengurangkan tekanan CSF tanpa menyebabkan pengurangan elektrolit dan nutrisi.

Objektif

Untuk mengenalpasti sama ada VSGS boleh mencapai lencongan sementara CSF bagi pesakit dewasa berbanding EVD, untuk mengenalpasti sama ada lencongan sementara ini dapat mengelakkan lencongan kekal, dan untuk mencari insiden komplikasi intrakranial seperti ventriculitis dan skala Rankin (diubahsuai), sepanjang masa kedua-dua jenis cara lencongan CSF itu diperlukan.

Kaedah

Ini adalah satu kajian rekod pesakit. Data yang diperolehi daripada nota-nota kes 50 pesakit yang menghidapi hidrosefalus akut: 26 mengalami pendarahan intraventrikal, 10 mengalami pendarahan aneurisma, 8 pesakit trauma, dan 6 pesakit yang mendapat jangkitan. Kesemua pesakit-pesakit ini telah menjalani pembedahan lencongan sementara CSF di Hospital Queen Elizabeth II antara tahun 2013 dan 2015. Pesakit-pesakit ini mendapat rawatan susulan dari tarikh rawatan sehingga resolusi hidrosefalus. Maklumat penting seperti keperluan lencongan CSF kekal dan komplikasi pembedahan direkod dalam borang yang disediakan.

Keputusan

Sejumlah 21 (42%) pesakit menjalani rawatan EVD dan 29 (58%) pesakit menjalani rawatan VSGS. Sebanyak 37 (74%) pesakit tidak memerlukan shunt kekal; 24 (64.8%) daripada mereka adalah daripada kumpulan VSGS (p=0.097). EVD mempunyai jumlah komplikasi intrakranial yang signifikan (44.1%) berbanding dengan VSGS (23.5%), dengan $p < 0.026$.

Kesimpulan

Meskipun setiap modaliti rawatan mempunyai komplikasi tersendiri, kajian ini menunjukkan bahawa VSGS adalah setara dengan EVD sebagai langkah lencongan sementara CSF. Disebabkan tiada signifikan secara statistik antara kedua-dua kaedah, VSGS adalah satu pilihan yang baik kerana mempunyai nilai klinikal, dengan potensi untuk kesinambungan rawatan pesakit di pusat-pusat yang tiada servis neurosurgikal, berbanding dengan EVD. VSGS didapati mempunyai kurang komplikasi intrakranial berbanding dengan EVD, dan penemuan ini adalah signifikan secara statistik.

ABSTRACT

Title

Comparison between Ventriculosubgaleal Shunt and Extraventricular Drainage to treat Acute Hydrocephalus in Adults at Hospital Queen Elizabeth between 2013 and 2015: A Retrospective Study

Authors

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Introduction

Hydrocephalus is defined as an inappropriate amount of cerebrospinal fluid (CSF) within the intracranial space at an inappropriate pressure. The decision to treat hydrocephalus is based on its various aetiologies. Transient alterations of CSF hemodynamics due to conditions such as subarachnoid and intraventricular haemorrhages, meningitis, and external compression from tumours may resolve after treatment; thus, temporary CSF diversion can be considered. A ventriculosubgaleal shunt (VSGS) can been used for temporary CSF diversion because it is a simple and rapid method, and establishes CSF decompression without causing electrolyte and nutritional losses.

Objectives

To study the efficacy of VSGS as a means of temporary CSF diversion, compared to EVD in adult hydrocephalus patients; to evaluate the outcome in terms of avoiding a permanent shunt, and to look for incidences of intracranial complications such as ventriculitis and modified Rankin scale, between the year 2013 and 2015.

Methods

This is a retrospective review of records. The data has been acquired from case notes of 50 patients with acute hydrocephalus: 26 secondary to intraventricular haemorrhage, ten from aneurysm rupture, eight post-trauma and six from infection. All these patients had undergone cerebrospinal fluid diversion in Hospital Queen Elizabeth II between 2013 and 2015. The patients were followed-up from the date of treatment until the resolution of hydrocephalus, where parameters such as shunt dependency and complications were documented in a pro forma.

Results

A total of 21 (42%) patients underwent EVD insertion and 29 (58%) underwent VSGS. Thirty-seven (74%) patients did not require a permanent shunt; 24 (64.8%) of them were from the VSGS group (p=0.097). EVD had more intracranial complications (44.1%) compared with VSGS (23.5%), with a statistically significant p value of 0.026.

Conclusion

While each treatment modality has its own complications, this study shows that VSGS is comparable with EVD as a temporary CSF diversion measure. As there are no statistical differences between these two modalities, VSGS is a viable option that has clinical value, with the possibility of continuation of treatment for such patients in non-neurosurgical centres, as opposed to patients with EVDs. Also, VSGS has statistically significant less intracranial complications compared with EVD.

Keywords

Hydrocephalus, extraventricular drainage, EVD, ventriculosubgaleal shunt, VSGS, cerebrospinal fluid diversion, CSF, permanent shunt, ventriculoperitoneal shunt.

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Mr. (Dr) Pulivendhan Sellamuthu: Supervisor

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Prof. Zamzuri Idris: Co-supervisor

INTRODUCTION

Hydrocephalus is a term derived from Greek: *hydro* meaning water and *kefale* meaning skull. It is defined as the state of excessive intracranial accumulation of cerebrospinal fluid (CSF) in the ventricular system of the brain (Richard *et al.*, 2004). It is frequently, but not always, characterised by ventriculomegaly or signs of raised intracranial pressure (ICP).

Hydrocephalus is the result of excessive production, circulation or absorption of CSF. It can be classified into communicating or non-communicating based on its underlying aetiology. Both forms can be congenital or acquired, and the management can be challenging and complex. Because the aetiologies and clinical presentations of hydrocephalus are so various, many treatment options must be considered, ranging from temporary to permanent surgical options.

Temporary methods in the management of acute hydrocephalus are commonly required. Several procedures and devices had been proposed, such as external ventricular drainage (EVD), repeated lumbar drainage, repeated lumbar puncture, Ommaya reservoir insertion for frequent tapping or ventricular subgaleal shunt (VSGS). All those methods are routinely used in clinical practice, but which of these procedures is chosen depends on many factors, including medical, patient and environmental factors.

The primary treatment goal for hydrocephalus must be normalization of impaired CSF flow, aimed at achieving a state of arrested hydrocephalus (Oi, 2005). All those temporary CSF diversion methods have their intrinsic drawbacks, and there is no consensus over the treatment of hydrocephalus.

Even after temporary methods in the management of hydrocephalus, some patients will not need any further treatment, while many others will require a permanent surgical solution (Peretta *et al.*, 2007). For those patients who need a definitive treatment, there are 2 options: either placement of permanent CSF diversion device or neuro-endoscopic procedures.

CSF diversion with a permanent ventriculoperitoneal shunt (VPS) is commonly related to multiple complications, with frequency of up to 50% in the first 2 years of operation (Drake *et al.*, 1998). Complications related to permanent shunt including obstruction, malposition, disconnection, and infection may bring about the requirement of at least 1 further operation, adding potential morbidity and mortality. To minimize the problems connected with VPS at time of implantation, the CSF has to be clear, with low protein levels and no clots or debris present in the ventricles. Until the VPS can be inserted, temporary CSF diversion is indicated (Nagy *et al.*, 2013).

Neuro-endoscopic procedures can be the choice of treatment but requires improvement of endoscopic technology and skills, especially in developing countries (Stagno *et al.*, 2013). Endoscopic third ventriculostomy (ETV) is one such neuro-endoscopic procedure, but it is indicated for obstructive hydrocephalus. Communicating hydrocephalus has traditionally been a contraindication for ETV. Recent evidence shows that ETV may be successful in some normal pressure hydrocephalus patients, or may be indicated if there is a lack of desired effects after shunting, or with infectious complications associated with VPS (Yadav *et al.*, 2012).

Alternatively, EVD and VSGS have been used in our centre for temporary CSF diversion because both are simple and rapid methods, establishing CSF decompression. VSGS provides physiologic drainage of CSF and protects the brain by dampening the pressure wave. Some amount of CSF and its contents are probably reabsorbed in the subgaleal space, thereby reducing protein and electrolytes loss (Köksal and Öktem, 2010).

In the attempt to avoid permanent shunt and the need for revision, which adds potential morbidity and mortality, multiple methods have been suggested, including endoscopic treatment for obstructive hydrocephalus, treating the underlying causes such as tumour resection, and haematoma evacuation. Koksal and Oktem performed VSGS for 25 patients and 3 of them with grade 1 and 2 germinal matrix haemorrhage (12%) did not require permanent shunts (Köksal and Öktem, 2010). Kariyattil et al performed VSGS for 21 meningitic hydrocephalus patients and one of them did well without any further shunt (Kariyattil *et al.*, 2008). For IVH due to ICB and SAH, 50% of patients who treated only with EVD required permanent shunt (Basaldella *et al.*, 2012).

This is a retrospective observation of acute hydrocephalus adult patients due to different aetiologies, given two different treatments (VSGS and EVD), as their dependency of permanent shunt was yet to be determined at the time of presentation in Hospital Queen Elizabeth between 2013 and 2015. We determined the outcome in terms of avoiding permanent shunt, number of procedure required, and complications due to each treatment modality.

CHAPTER 1: HYDROCEPHALUS

1.01: PATHOPHYSIOLOGY

Cerebrospinal fluid (CSF) flows in the ventricular system in the brain. Ventricular anatomy includes two lateral C-shaped ventricles separated by a midline septum pellucidum, where each has a frontal foramen of Monroe that connects into the third ventricle; the third ventricle connects posteriorly with the fourth ventricle through the Aqueduct of Sylvius; the fourth ventricle sits between the brainstem anteriorly and the cerebellum posteriorly and drains CSF through the central foramen of Magendie and two lateral foramens of Luschka to be spread to around the brain and spinal cord.

Physiologically, CSF is a clear and colourless fluid produced by choroid plexus within the ventricles (80%), interstitial space, ventricular ependymal and nerve root sleeves dura mater; reabsorbed by arachnoid villi of the dural venous sinuses, choroid plexus and cervical lymphatics back into the venous system driven by hydrostatic gradient.

Daily CSF production and volumes: Newborns: 25mls produced per day, with a total volume of 5mls at any one time; adults: 0.3-0.35ml/min (450-750 ml/day) produced, with a total volume of 150ml at any one time. The 150mls of CSF volume is reached by the age of 5 years old. Production is pressure independent (Kershenovich, 2014).

The pathophysiology of hydrocephalus can be further divided into 4 forms: disorders of CSF circulation, absorption, production or dynamics.

1. Disorders of CSF circulation

   This form of hydrocephalus results from obstruction of the pathways of CSF circulation. This can occur at the ventricles or any other point within the CSF space up to the arachnoid villi. Tumour, haemorrhages, congenital malformations and infections can cause obstruction at any point in the pathways.

2. Disorders of CSF absorption

   This form of hydrocephalus is the result of interfering with CSF absorption at the arachnoid granulations such as cerebral venous sinus thrombosis, meningitis, subarachnoid haemorrhage or superior vena cava syndrome.

3. Disorders of CSF production

   This is the rarest form of hydrocephalus. Choroid plexus papillomas and choroid plexus carcinomas can secrete CSF in excess to its absorption capacity.

4. Unclassified or not well understood disorders of CSF dynamics

   Some form of hydrocephalus cannot be classified clearly. This group of hydrocephalus include normal pressure hydrocephalus. Besides enlargement of the ventricles, disturbed CSF dynamics can also lead to other diseases like idiopathic intracranial hypertension, syringomyelia and Tarlov’s cyst.

1.02: NATURAL HISTORY AND CLINICAL PRESENTATION

The various types of hydrocephalus will present differently in different age groups. Acute hydrocephalus in adults is related to the elevation of intracranial pressure (ICP), manifested by a clinical triad of headache, nausea or vomiting, and papilledema. Headache tends to be poorly localized or bifrontal. It gets worse when recumbent due to maximal ICP when flat. It can be temporarily relieved with analgesics and upright posture. As the ICP rises, headaches become more likely to awaken the patient from sleep, and more severe and resistant to analgesics. Nausea and vomiting, like headache, tend to accompany raised ICP. Papilloedema is a more common finding in the hydrocephalus of adults. Abducens or 6th cranial nerve palsy can occur as a false localizing sign in hydrocephalus. Episodic visual obscuration or sometimes described as "greying" accompanies dangerous pressure waves and suggests the need for emergent ventricular drainage (Rengachary and Ellenbogen, 2005).

However, in infants, irritability and poor head control can be the only and early signs of hydrocephalus. As the frontanelles and sutures are still open, infants can present with bulging frontanelles, dilated scalp veins and increasing head circumference. When the third ventricle dilates, the patient can present with Parinaud syndrome (upward palsy with a normal vertical Doll response) or the setting sun sign (Parinaud syndrome with lid retraction and increased tonic downgaze). When advanced, hydrocephalus presents with coma and haemodynamic instability, which can lead to death.

1.03: EPIDEMIOLOGY AND DEMOGRAPHICS

The incidence of paediatric hydrocephalus as an isolated congenital disorder is approximately 1/1000 live births. The prevalence and incidence of hydrocephalus in developed nations are estimated as 0.9 to 1.2 per 1000 live births and 0.2 to 0.6 per 1000 live births respectively. No reliable estimate is available in most of the developing nations, but its incidence is likely to be higher due to inadequate antenatal diagnosis, high rates of untreated or poorly treated perinatal infections, and nutritional deficiencies (Stagno *et al.*, 2013).

Adult hydrocephalus has no documented incidence or prevalence in Malaysia. In Hospital Kuala Lumpur, a general hospital with neurosurgical services located in the capital city of Malaysia, performed 400 cases of CSF diversion in adult, aged 14 to 73 years old between December 2006 to December 2008. Those hydrocephalus were secondary to subarachnoid haemorrhage (SAH), spontaneous or traumatic intraventricular haemorrhage (IVH), intraparenchymal bleed or tumour associated hydrocephalus (Omar and Haspani, 2010).

1.04: DIAGNOSTIC EVALUATION

Hydrocephalus can be evaluated by computed tomography (CT) or magnetic resonance imaging (MRI) of the brain to visualize the entire ventricular system. There is a range of normal ventricular size changes with age, rendering absolute measurements of the ventricular dimensions of little use. Some radiological features are strongly suggestive of hydrocephalus when occurring in combination (Tandon and Ramamurthi, 2011).

Hydrocephalus is suggested when the size of both temporal horns are 2mm or more, when the Sylvian fissure, inter-hemispheric fissures and cerebral sulci are not visible, or when the ratio FH/ID is more than 0.5, where the FH is the largest width of the frontal horns and the ID is the inner diameter from inner-table to inner-table at the level in the axial cut of CT brain.

Other features suggestive of hydrocephalus are:

1. Ballooning of third ventricle and/or frontal horns of lateral ventricle, with the appearance of “Mickey mouse” ventricles.
2. Periventricular low density on CT, or periventricular high intensity signal on T2-weighted MRI secondary to transependymal absorption of CSF, especially at the tips of the frontal, occipital and temporal horns.
3. Evans ratio of the frontal horns’ largest width to maximal biparietal diameter measured in the same CT axial slice more than 0.3 (Figure 1-03).
4. Sagittal MRI may show thinning and/or upward bowing of the corpus callosum.

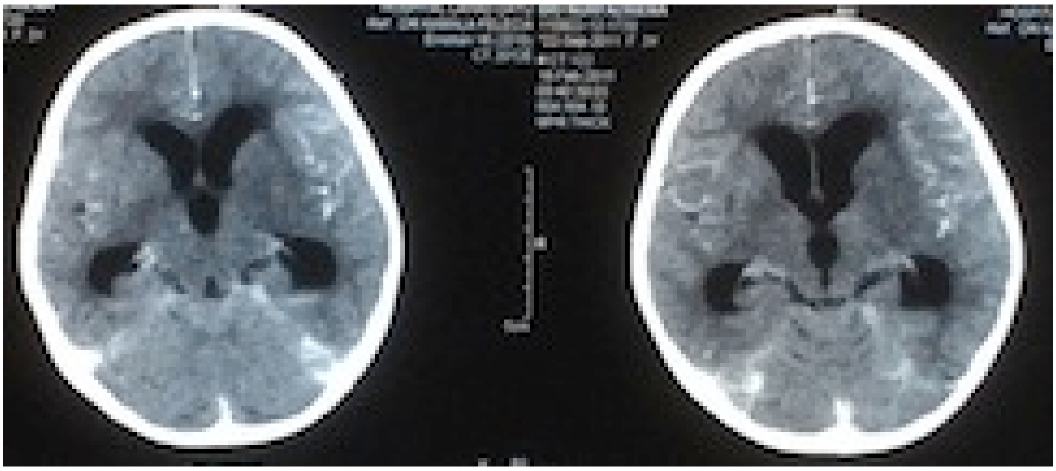

Figure 1-01: Axial view of plain CT brain showing diffuse subarachnoid haemorrhage with hydrocephalus.

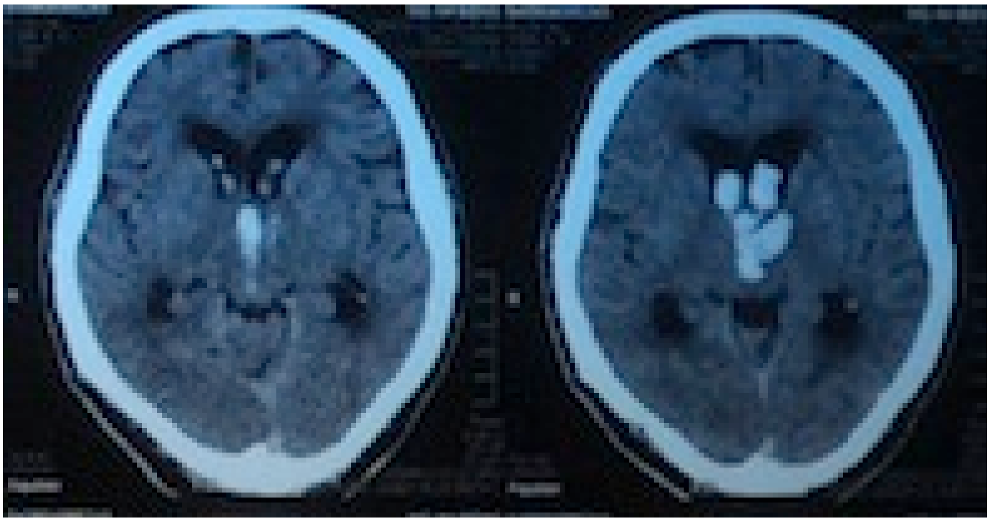

Figure 1-02: Axial view of plain CT brain showing left thalamic haemorrhage with intraventricular extension with hydrocephalus. (Ishii *et al.*, 2008)

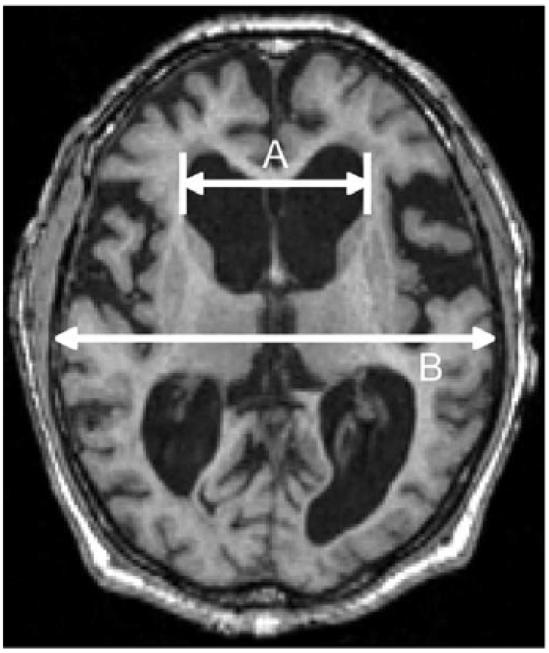

Figure 1-03: Axial view of T1WI of MRI brain showing hydrocephalus. A= largest width of frontal horns; B= maximal biparietal diameter (Ishii *et al.*, 2008).

1.05: CLASSIFICATION

Hydrocephalus can be classified based on onset, symptoms, pathology and other specific types as described by Oi and Shizuo (Table 1-01). Their clinical and pathophysiology features may even change over time following treatment.

Table 1-01: Classification of hydrocephalus (Oi, 2005)

Entity involved	Parameters	Subtypes
Patient	Onset	Congenital/acquired Fetal/neonatal/infantile/child/adult/geriatric Acute/subacute/chronic
	Causes	Primary/secondary/idiopathic
	Underlying lesions	Dysgenetic/posthaemorrhagic/post-SAH/post-IVH/postmeningitic/post-traumatic/brain tumour/spinal cord tumour/brain abscess/arachnoid cyst/cysticercosis, etc.
	Symptomatology	Macrocephalic/normocephalic/microcephalic Occult/symptomatic/overt Coma/stupor/dementia Hydrocephalus/parkinsonism complex. Etc.
Hydrocephalus	Pathophysiology	Communicating/non-communicating
	- CSF circulation	Non-obstructive/obstructive External/internal/interstitial Isolated compartments: UH/isolated fourth ventricle/isolated rhombencephalic/Iisolated central canal dilatation/double-compartment hydrocephalus/disproportionately large fourth venricle, etc.
	- CSF dynamics	High/normal
	- Chronology	Slowly progressive/progressive/long-standing/arrested
Treatment	Post-shunt	Shunt-dependent/shunt-independent Slit-like ventricle/slit ventricle syndrome, etc.

Classifying hydrocephalus based on communicating or non-communicating is useful in terms of management and in deciding the safeness to perform lumbar puncture. Communicating hydrocephalus is characterized by pan-ventricular dilatation and occurs as a result of obstruction to the flow of CSF in the subarachnoid space, distal to the foraminal of Luschka and Magendie. Therefore, there is communication between the ventricles and the subarachnoid space. This condition is commonly caused by infection, haemorrhage, or is idiopathic. Lumbar puncture is generally safe.

Non-communicating hydrocephalus is characterized by a pattern of ventricle dilatation that reflects the site of obstruction. Non-communicating hydrocephalus is also known as obstructive hydrocephalus, as the term non-communicating denotes obstruction within the ventricular system or at the level of the outlets of the fourth ventricle. Common aetiologies of obstructive hydrocephalus are as shown in Figure 1-04. Lumbar puncture may be dangerous for patients with non-communicating hydrocephalus.

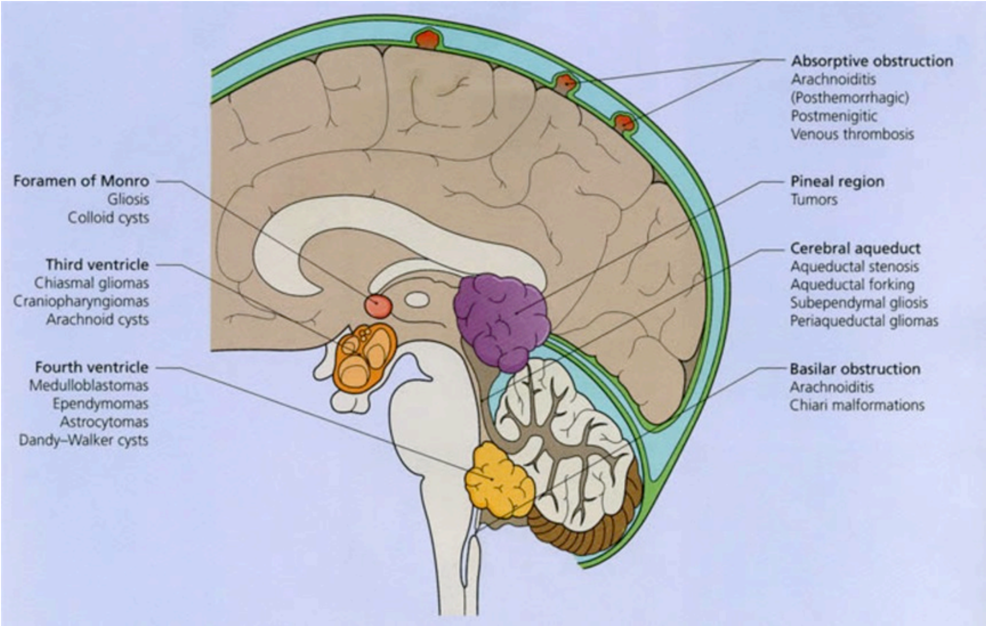

Figure 1-04: Common sites and causes of cerebrospinal fluid obstruction (Rengachary and Ellenbogen, 2005).

1.06: TREATMENT

Medical therapy is usually a temporary measure. Hydrocephalus secondary to transient conditions, such as cerebral venous sinus thrombosis, meningitis, neonatal intraventricular haemorrhage, medical therapy can be effective.

Acetazolamide is a carbonic anhydrase inhibitor; it is given 25mg/kg/day in 3 divided doses orally, increased by 25mg/kg/day until 100mg/kg/day is reached. Side effects of acetazolamide are electrolyte imbalance, lethargy, tachypnea, diarrhea and paresthesias, such as tingling sensation in the fingertips.

Frusemide is a diuretic agent, start simultaneously with acetazolamide, given 1mg /kg/day in 3 divided doses, orally. Electrolytes and fluid balance must be monitored carefully with serial electrolyte while giving these medications. Maintain medical therapy for a trial of 6 months, and then taper the dosage over 2-4 weeks.

However, medical therapy should only be considered as an adjunct to definitive treatment or as a temporizing measure. Weekly computed tomography of the brain or close observation for evidences of acute hydrocephalus is essential to detect progressive ventriculomegaly, which needs surgical decompression of the ventricle.

Surgical intervention is the definite treatment for hydrocephalus if it progresses and is associated with increased ICP. It can be achieved by diverting the CSF flow from the ventricular system to where it is readily absorbed or by draining out continuously or intermittently. The decision for definitive or temporary CSF shunting depends on the disease's pathology; transient alteration in CSF hydrodynamics such as infection, haemorrhage, or tumour might resolve after treatment, and a temporary shunt can be considered. Endoscopic procedure can be considered for patients with obstructive hydrocephalus. Correction of the causative factor may solve the hydrocephalus, such as removal of tumour or haematoma.

CHAPTER 2: LITERATURE REVIEW

2.01: CLASSIFICATION OF HYDROCEPHALUS

Hydrocephalus is the cause of major morbidity for children and adults across the globe (Stagno *et al.*, 2013). As mentioned in the previous chapter, hydrocephalus can be classified into communicating and non-communicating, which can affect the decision of the treatment based on the different aetiologies.

Non-communicating or obstructive hydrocephalus can be congenital or acquired, causing internal or external obstruction at any point of the CSF pathway within the ventricle. Congenital aetiologies include Chiari 1 malformation, aqueductal stenosis, Dandy Walker malformation, and arachnoid cyst. Acquired aetiologies include masses and post-operative hydrocephalus.

Communicating or non-obstructive hydrocephalus is CSF blocked at the arachnoid granulation. Congenital causes are Chiari II malformation, intrauterine infection, germinal matrix haemorrhage and syndromic craniosynostosis. Acquired communicating hydrocephalus can be secondary to infection, post haemorrhage due to trauma or spontaneous intracranial bleed, post operation, or dural venous thrombosis.

Hydrocephalic syndromes such as acute, chronic and arrested hydrocephalus may affect the urgency of CSF diversion and hence the timing for surgery intervention (Kershenovich, 2014).

Acute hydrocephalus can occur within hours from the onset of obstruction, characterized by a rapid and progressive rise in intracranial pressure if the cranial sutures are closed. These patients become progressively obtunded and exhibit signs of central trans-tentorial herniation with increasing intracranial pressure, and rapidly followed by death unless urgent treatment is given.

Chronic hydrocephalus occurs when the ventricular obstruction is incomplete; compensatory changes like expansion of the skull if the cranial sutures are open, contraction of the cerebral vascular volume or brain atrophy can prevent a rapid death.

Arrested hydrocephalus is chronic hydrocephalus with ventriculomegaly or progressively smaller ventricles where there is neither increased intracranial pressure (ICP) nor new symptoms. However, establishing the diagnosis of arrested hydrocephalus is difficult and needs a longer period of observation for signs of raised ICP or neurological function.

CSF shunts are the most common treatment for hydrocephalus available worldwide. However, shunts are frequently related to high complications and need re-intervention. There is no consensus over the treatment of hydrocephalus. Because the aetiology and clinical presentation of hydrocephalus are so various, many treatments must be considered, ranging from transient to permanent surgical options.

There are a few types of shunts being proposed. Definitive CSF shunts include ventriculoperitoneal shunts (VPS), ventriculopleural shunts, ventriculoatrial shunts and lumboperitoneal shunts. Other not commonly used CSF shunts are ventricular-gallbladder shunts and ventricular-ureter shunts (Drake and Sainte-Rose, 1995).

Temporary CSF shunts include extraventricular drainage (EVD), external lumbar drainage, ventriculosubgaleal shunts (VSGS), ventricular catheter to a subgaleal reservoir, or repeated lumbar puncture. These temporary CSF shunts procedures are considered where the alteration of hydrodynamic of the CSF is transient, such as haemorrhage, infection or tumour. However, repeated tapping of CSF only provides intermittent relief from raised intracranial pressure (Rahman *et al.*, 1995). External lumbar drainage or EVD provides continuous drainage but is difficult to maintain for long periods due to the risk of secondary infection. It also makes the patients confined to bed for long periods, and monitoring by a neurosurgery team is required (Kariyattil *et al.*, 2008).

Endoscopic third ventriculostomy (ETV) may be considered for obstructive hydrocephalus with patent subarachnoid spaces and adequate CSF absorption. Success rate exceeding 75% for hydrocephalus patients with acquired aqueductal stenosis or tumour obstructing third or fourth ventricle. However, for patients presented with haemorrhage or infection have generally demonstrated poor response to ventriculostomy, less than 50% success rate (Chakraborty *et al.*, 2012).

2.03: DECISION TO TREAT ACUTE HYDROCEPHALUS

Temporary or permanent CSF shunt procedures proposed are all routinely used in clinical practice, but choosing which one to adopt depends on many factors, including medical, patient and environmental factors. No one particular shunt procedure is suitable for all patients. Since a permanent shunt insertion is a lifetime commitment to an imperfect device, all attempts should be made to avoid a permanent shunt. The restoration of a normal CSF circulation will always be better than any artificial drainage (Drake and Sainte-Rose, 1995).

Hydrocephalus due to brain tumour in the posterior fossa will be cured by tumour removal in a large number of patients, up to 80% (Epstein and Murali, 1978). There is a general consensus that a preoperative shunt should be avoided since it may induce shunt dependency in patients who are no longer hydrocephalic after tumour surgery and do not need a shunt.

For haemorrhagic hydrocephalus following germinal matrix haemorrhage, head injury, rupture of vascular anomalies or aneurysm, the consequences of CSF hydrodynamics are similar. At the acute stage, clots generated by the bleeding create mechanical obstacles to CSF flow in the narrowest parts of its pathways: in the aqueduct of Sylvius, cisternae, subarachnoid spaces or arachnoid villi. CSF viscosity following bleeding is insufficient to induce hydrocephalus. At the chronic stage, leptomeningeal fibrosis may develop in some cases, leading to a permanent increased resistance to CSF flow. Hence not all of these patients will become permanently hydrocephalus. Treatment of the acute phase of the ventricular enlargement using a temporary method of drainage may save a significant number of patients from a permanent shunt (Gurtner *et al.*, 1992).

Hydrocephalus caused by meningitis is communicating hydrocephalus, reflecting failure of CSF circulation in the basal cisterns and failure of resorption through the arachnoid granulations (Wang *et al.*, 2005). In the retrospective study, 21% (28/136) of meningitis patients had been detected to have hydrocephalus. Among these 28 patients, 7 patients underwent EVD during the acute phase of bacterial meningitis; 4 of them survived with normal outcomes. It showed that therapeutic regimens for meningitis hydrocephalus should be designed to eradicate bacterial pathogens primarily, subsequently treating neurological complication such as hydrocephalus with CSF diversion.

Post-traumatic hydrocephalus (PTH) is quite variable, ranging from 0.7-29% based on worldwide literature (Sarkari *et al.*, 2010). PTH commonly occurs within the first year post-trauma. In many cases, initial brain damage leads to cerebral atrophy with secondary ventriculomegaly, also known as hydrocephalus ex-vacuo, which can give rise to a false impression of PTH. Kishore et al found that only 13.7% of patients with ventriculomegaly had PTH (Kishore *et al.*, 1978). SAH has been cited as an important pathology leading to hydrocephalus due to obliteration of subarachnoid spaces with fibrous thickening of lepto-meninges, particularly in the sulci of convexity and base of the brain (Foroglou and Zander, 1971). Decompressive craniectomy has been found to be associated with development of PTH by altering CSF pressure dynamics, mechanical blockage around convexities or inflammation of arachnoid granulations by post-surgical debris (Waziri *et al.*, 2007). PTH is a treatable complication of head injury with a favourable outcome and hence needs to be managed with surgical CSF diversion (Sarkari *et al.*, 2010).

Hydrocephalus due to tumour, PTH, post-haemorrhagic and post-infectious causes needs CSF diversion. The previous literature recommends a permanent VPS as a definitive treatment; however, the complications of shunt infections and blockage or malfunction can seriously affect the life of already handicapped patients. All attempts should ne made to avoid a permanent VPS if the alteration of CSF haemodynamic is transient, and due to all those pathologies and might resolve after treatment. For such cases, temporary methods must be considered. (Drake and Sainte-Rose, 1995). If the hydrocephalus is shunt-dependent, the CSF has to be clear with low protein level (less than 2g/L), and no clots or debris should be present in the ventricles to minimize the problems related to the VPS at the time of implantation (Nagy *et al.*, 2013). Temporary CSF diversion methods have to be considered until the permanent VPS can be inserted.

2.04: EXTRAVENTRICULAR DRAINAGE

EVD is a temporary method of ventricle decompression for acute hydrocephalus. It can drain out CSF by a combination of gravity and intracranial pressure via a ventricular tube connected outside the brain (Figure 2-01). The drainage rate depends on the height at which the EVD system is placed relative to the patient's anatomy, using the tragus as a referent point, which corresponds to the Foramen of Monroe.

EVD is used to relieve ICP by draining out CSF, monitor the intracranial pressure and for intraventricular delivery of antimicrobial or chemotherapy agents (Quinones-Hinojosa, 2012). EVD allows drainage of CSF continuously at a specific level; however, it requires sending CSF samples for surveillance and culture, and hence requires neurosurgical care in the hospital.

An EVD is inserted into the lateral ventricle at any point along the mid-pupilary line with a trajectory that is perpendicular to the skull. Frontal location is the most commonly used site, via the right Kocher's point because the right frontal lobe is part of the non-dominant hemisphere in most patients. Intra-operatively, patients lie supine with the head of bed slightly elevated around 20-30 degrees and the neck in a neutral position. The entry point on the scalp is measured and marked, and the shaved area is scrubbed and draped. Local anaesthesia is injected subcutaneously at the planned incision and at the drain exit sites. Incision is made down to the bone at the marked site, large enough to permit passage of the drill for making the burr hole on the skull. The dura is then punctured for the passage of the EVD catheter. The catheter with its stylet is inserted perpendicular to the brain surface to a depth no greater than 5cm below the inner table of the skull, the stylet then is withdrawn to ensure CSF flow. The distal end of the catheter is tunnelled under the galea to an exit site at least 5cm distant from the entry site. The catheter is secured to the scalp using a 2-0 silk suture. The incision closed in layers. The distal end of the catheter is connected to an adapter, and then to either a drainage system or a pressure transducer for ICP monitoring.

After EVD placement, it will be connected outside the brain to facilitate the drainage of CSF continuously. Once the CSF is clear from blood for post haemorrhagic hydrocephalus or infection for meningitis, the EVD is slowly raised and then clamped. The patient is considered successfully weaned off the EVD with the goal of removing it after a successful clamp trial. However, if a patient develops clinical changes (headache, altered mental status, nausea or vomiting), an ICP elevation above 20mmHg, leakage from the EVD site or worsening radiographic hydrocephalus after raising or clamping the EVD, then the weaning is considered a failure. EVD must be lowered or unclamped to drain the CSF continuously. There may be further attempts to wean the EVD. If the patient fails one or more clamp trials, a VPS is placed, as supported in a recent study by Lewis and Taylor, which showed a significant association between wean failure due to clinical changes and requirement of VPS placement (Lewis and Taylor Kimberly, 2014).

EVD carries a 1.1% risk of intra-cerebral haemorrhage with intraventricular extension, from which 0.5% requires surgical evacuation. The incidence of malposition of EVD requiring operative reposition is 3%, while the incidence of malfunction or obstruction is 6%. For aneurysmal subarachnoid haemorrhage, excessive CSF drainage can increase the transmural pressure across aneurysmal dome and increase the risk of re-bleeding in unsecured ruptured aneurysm (Connolly, 2002).

EVD systems expose the intraventricular environment to the exterior. The frequency of EVD-related infection at Hospital Kuala Lumpur was as high as 32.2% (Omar and Haspani, 2010). EVD-associated CSF infection can occur with the infection identified at a mean of 5.5 ± 0.7 days post insertion. The risk is higher with multiple elective EVD revisions. 48% of EVD-associated infection is by *Acinetobacter spp*. And is associated with potential morbidity and mortality. An EVD must be closely monitored in the neurosurgical unit as long as the draining is needed for improvement of CSF or resolution of hydrocephalus (Connolly, 2002) (Kariyattil *et al.*, 2008).