Thesis Title:
The Correlation Between Morphometric Measurements of Brain Ventricles and Head Circumference Among Hydrocephalic Infants in Gezira Trauma Centre: A Computerized Tomography Study 2017

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A Dissertation
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Department of Anatomy
Faculty of Medicine

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Dedication

To My Father …

To My Mother …

To My brother…

Thanks
ACKNOWLEDGMENT

I want to send my deepest gratitude to Dr. Mohamed Abdelsalam Nurien for his support, assistance and contribution from the beginning of data collection, providing me access, data and information, to the writing process until the completion of this thesis.

I would like to sincerely thank my co-supervisor Dr. Fiasal Nugud Abdeljaleel, for his guidance and support throughout this study.

In particular I would like to thank Dr. Mohamed Al-Mahdi Ali Saleh for his cooperation and permission to conduct this study in Gezira trauma center.

I express my heartfelt gratefulness to all staff of Gazira traumatology centre especially the radiology department for their help in the data collection, data analysis and writing of this thesis.

Thanks to my patients and their families for cooperation to whom I wish wellbeing and healthy long life.
The Correlation between Morphometric Measurements of Brain Ventricles And Head Circumference Among Hydrocephalic Infants in Gazira Trauma Centre: A Computerized Tomography Study 2017

Mohamed Soud Mohamed Saad Eldein

Abstract

**Background:** Hydrocephalus is a common developmental disorder that resulted due to imbalance between CSF inflow and outflow. It is associated with significant morbidity and mortality among children. One of the measurements used in assessment of hydrocephalus is head circumference which provide a cheap and easy tool for the assessment of growth, general health and nutritional status of infants as well as detection of intracranial pathology.

**The Aim of the study:** is to correlate ventricular measurements with Head circumference, age and gender among hydrocephalic infants in Gazira traumatology centre in the period between January 2017 to June 2017.

**Patients And Methods:** This is a prospective analytic hospital based study between January 2017 to June 2017 included all hydrocephalic infants who presented to Neurosurgery department in Gazira Trauma centre. A questionnaire was filled including the age, gender, head circumference measurement (in Cm) and the presence of spina bifida. The CT scan of the brain was reviewed and ventricular dimensions were measured. The data was processed using SPSS program version 22 to determine the statistical significance of the findings.

**Results:** sixty hydrocephalic infants were included. males were (60%) with male to female ratio 3:2. Most of the hydrocephalic infants were diagnosed at age group between 6–12 months while 25% had a co-morbid spina bifida. The mean head circumference was 46.2±6.2 cm. There was significant statistical differences in ventricular dimensions measurements according to age and gender (p value <0.05). The change in head circumference was associated with significant changes in the values of lateral and third dimensions measurements (p value <0.05 while there was no significant statistical differences in the fourth ventricle measurements according to head circumferences (p value >0.05).

**Conclusion:** The head circumference can predict changes in the lateral and third ventricular dimensions while may not correlate with fourth ventricular measurements in hydrocephalic infants.
مقارنة القياسات البنيوية لبطينات الدماغ مع قياس محيط الرأس وسط الرضع الذين يعانون من موه الرأس في مركز الجزيرة للإصابات: دراسة باستخدام التصوير المقطعي المحوسب 2017

الطالب / محمد سعود محمد سعد الدين

ملخص البحث

الخلفية:
موه الرأس هو نتيجة لعدم التوازن بين تدفق وتصريف السائل النخاعي وهو اضطراب نمو شائع الحدوث يتسبب بمعدل عالي من المضاعفات، ووتطور الأمراض.

محيط الرأس هو واحد من قياسات النمو والتطور الأكثر استخداما التي توفر أداة رخيصة وسهلة لتقديم نمو الجسم والصحة العامة والبيئة التغذوية للرضع وكذلك الكشف عن الأمراض داخل الدماغ.

الهدف:
دراسة مدى ارتباط قياسات بطينات الدماغ مع محيط الرأس والعمر والجنس بين الرضع المصابين بموه الرأس في مركز الجزيرة للإصابات في الفترة ما بين يناير 2017 وحتى يونيو 2017.

المرضى وطرق البحث:
هذه دراسة تحليلية مستندة إلى دراسة أجريت في الفترة بين يناير 2017 إلى يونيو 2017 ضمت الدراسة 60 طفلًا مصابًا بموه الرأس تم استقبالهم في قسم جراحة المخ والأعصاب في مركز الجزيرة للأصابات. تم عمل استبانات شاملة للمرض والجنس وقياس محيط الرأس والتحقق من وجود السنسنة المشقوقة. وتمت مراجعة المسح المقطعي للدماغ وتم قياس أبعاد البطين الجانبي والثالث والرابع. تمت معالجة البيانات باستخدام برنامج SPSS الإصدار 22.

النتائج:
كانت سبعة من المجموعة الدراسة ذكور ونسبة الذكور إلى الإناث 3:2. تم اكتشاف موه الرأس في معظم الأطفال في الفئة العمرية من 6-12 شهرًا بينما المسنة المشقوقة في 25٪ منهم. متوسط محيط الرأس من مجموعة الدراسة كان 46.2 ± 6.2 سم. كانت هناك فروق ذات دلالة إحصائية في أبعاد البطين الجانبي والثالث والرابع حسب العمر والجنس (ب < 0.05). كان التغير في محيط الرأس مرتبطة بغيرات معنوية في متوسط قيمة الأبعاد الجانبية والثالثة (ب < 0.05) في حين لم تكن هناك فروق ذات دلالة إحصائية في متوسط قياسات البطين الرابع حسب محيط الرأس (ب > 0.05).

الخلاصة:
يمكن لمحيط الرأس التنوب بالتغيرات في الأبعاد البطينية الدماغية الجانبية والثالثة في حين لا يرتبط مع القياسات البطينية الدماغية الرابعة في الرضع المصابين بموه الرأس.
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<tr>
<td>AHI</td>
<td>Anterior Horn Index</td>
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<td>AHL</td>
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<td>AHW</td>
<td>Anterior Horn Width</td>
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<td>Aqu</td>
<td>Aqueduct of sylvian</td>
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<td>FVH</td>
<td>Fourth ventricular Height</td>
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<td>FVL</td>
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<td>H C</td>
<td>Head Circumference</td>
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<td>IHH</td>
<td>Anterior Horn Height</td>
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<td>Inferior Horn Width</td>
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<td>LVH</td>
<td>Fourth ventricular Height</td>
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<td>LVL</td>
<td>lateral ventricular length</td>
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<td>Fourth ventricular Width</td>
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<td>PHL</td>
<td>Posterior Horn Length</td>
</tr>
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<td>PHW</td>
<td>Posterior Horn Width</td>
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<tr>
<td>TVH</td>
<td>Third ventricular Height</td>
</tr>
<tr>
<td>TVL</td>
<td>Third ventricular Length</td>
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<td>TVW</td>
<td>Third ventricular Width</td>
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1. INTRODUCTION

1-1 General Introduction:

The human cerebral ventricular system contains a series of interconnecting spaces and channels which originates from the central lumen of embryonic neural tube. Cerebrospinal fluid filled ventricular system is an essential part of brain. The ventricular system in the cerebral hemispheres consists of two lateral ventricles; midline third and fourth ventricles connected by inter ventricular foramen and aqueduct of Sylvius respectively (Standring et al., 1995).

Hydrocephalus is the most common developmental problem encountered in infants. The reported incidence of infantile hydrocephalus is approximately 2 – 4 / 1000 live births. It ranks as the 2nd most common congenital neurological malformation in North America, after spinabifia (Kulkarni, 2004). The natural history of unshunted hydrocephalus was studied, and it revealed a 46 % survival rate for 10 years (Laurance and Coates 1962). Of the surviving population, 62 % suffered from intellectual impairment (Laurance and Coates, 1962). Children who are adequately treated for hydrocephalus have a considerably better outcome. Their survival rate after 10 years is 95 %, and only 30 % have impaired intellectual function (Shurtleff et al., 1973).

Understanding the normal and abnormal anatomy of the ventricular system of brain is helpful for clinicians, neurosurgeons, and radiologists in day-to-day clinical practice (Srijit and Shipra, 2007). Computerized Tomography is a revolutionary method of utilizing x-rays in the diagnosis. It is developed by Hounsfield GN, which provides images of transverse slices of brain without the use of contrast media in plain study (Gawler et al., 1976; Sabattini, 1982; Gomori et al., 1984). The advent of brain computerized tomography (CT) has afforded a generally safe, non-invasive means of examining the interior of the head, including evaluation of ventricular size (Gawler et 2 al., 1976; Gallia et al., 2006).
Morphometric analysis of cerebral ventricular system is important for evaluating changes due to growth, ageing, intrinsic and extrinsic pathologies (Le May, 1984; Aziz, 2004). It is helpful in the diagnosis and classification of hydrocephalus and in assessment, follow-up of enlargement of ventricular system during therapy (ventricular shunts) (Losowska-Kaniewska and Oles, 2007; Ambarki et al., 2010).

The study of shape and size of ventricular system recently has become a main focus of interest in studies of some neuropsychiatric diseases like schizophrenia and Alzheimer’s disease (McCarley et al., 1989; Ashtari et al., 1990; Gallia et al., 2006) and chronic alcoholism (Rohlfing et al., 2006). Knowledge of anatomy of cerebral ventricular system is important for endoscopic neurosurgery (Duffner et al., 2003).

The most commonly used anthropometric measurements for the assessment of growth in child clinics are length/height, weight and head circumference (HC) or occipito-frontal circumference reflecting general health and nutritional status of infants(Gale et.al 2006). HC can help us monitor the growth of the brain, because cognitive function, intracranial volume, and brain volume are closely related to the magnitude of HC (Coronado et.al 2012, Wilson & Williams 2007). This research study the correlation of ventricular dimensions measured using CT scan with age, gender and head circumference among hydrocephalic infants.
1.2 PROBLEM STATEMENT AND JUSTIFICATION

There is large data available in literature and radiology practice of the ranges of the sizes of cerebral ventricles among normal population but the data is ambiguous about pattern of change of ventricular measurement in hydrocephalic infants. The first tool of clinical detection of hydrocephalus in infant is attributed to head circumference specially in developing countries. This raise the need for correlation between head circumference and ventricular measurements in detection of the progression of hydrocephalus and the effect of management. As well as the need to determine the pattern of change in ventricular measurement according to age and gender.

1.3 OBJECTIVES:

1.3.1 General objective:
To study the correlation of ventricular measurements with Head circumference, age and gender among hydrocephalic infants in Gezira Trauma Centre between January to July 2017.

1.3.2 Specific objectives:
1- To estimate the mean value of ventricular dimensions among hydrocephalic infants in Gezira Trauma Centre.
2- To correlate between age and ventricular dimensions among hydrocephalic infants in Gezira Trauma Centre.

3- To correlate between gender and ventricular dimensions among hydrocephalic infants in Gezira trauma centre.

4- To evaluate the relation between head circumference and the rate of change in ventricular measurements in patients of hydrocephalus.
LITERATURE REVIEW

2-1 Background:

The ventricular system is embryologically derived from the neural canal, forming early in the development of the neural tube. The Three brain vesicles (prosencephalon or forebrain, mesencephalon or midbrain, and rhombencephalon or hindbrain) developed by the end of the first gestational month. (FitzGerald & FolanCurran, 2002)

The lateral ventricles are the largest cavities of the ventricular system and occupy large areas of the cerebral hemispheres. Each ventricle is a roughly C-shaped cavity lined with ependymal and filled with CSF. It is divided into a body, which occupies the parietal lobe, and from which anterior, posterior and inferior horns extend into the frontal, occipital and temporal lobes respectively. Each lateral ventricle opens through an interventricular foramen into the third ventricle (Lowery and Sive, 2009).

During early development, the septum pellucidum is formed by the thinned walls of the 2 cerebral hemispheres and contains a fluid-filled cavity, named the cavum, which may persist. (FitzGerald & FolanCurran, 2002)

The third ventricle is the narrow vertical cavity of the diencephalon. The fornix and the corpus callosum are located superiorly. The lateral walls are formed by the medial thalamus and hypothalamus, the anterior wall is formed by the commissure, the lamina terminalis, and the optic chiasm, the floor is formed by the infundibulum while the posterior wall is formed by the pineal gland and habenular commissure. 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. (FitzGerald & FolanCurran, 2002, Waxman SG, 2000)

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 anterior-inferior to the cerebellum. The superior cerebellar peduncles and the medullary vela form the roof of the fourth ventricle. The apex is the extension of the ventricle up into the cerebellum. The floor of the fourth ventricle is named the rhomboid fossa. The lateral recess is an extension of the ventricle on the dorsal inferior cerebellar peduncle. Inferiorly, it extends into
the central canal of medulla. The fourth ventricle communicates with the subarachnoid space through the lateral foramen of Luschka, and median foramen of Magendie, located in the roof of the ventricle. (FitzGerald & Folan Curran, 2002; Waxman SG, 2000)

CSF is produced primarily by the choroid plexus, which is responsible for 60 to 80 percent of CSF production. The choroid plexus tissue is located in each cerebral ventricle, and consists of villous folds lined by epithelium with a central core of highly vascularized connective tissue. The total volume of CSF in infants is approximately 50 mL, compared with 125 to 150 mL in normal adults. In adults, approximately 25 percent of the CSF is within the ventricular system. This fluid flows through the ependymal layer into the cerebral ventricles or spinal central canal.

2.2 Hydrocephalus:

Hydrocephalus can be defined broadly as a disturbance of cerebrospinal fluid (CSF) formation, flow, or absorption, leading to an increase in volume occupied by this fluid in the central nervous system (CNS). (Rekate HL et al., 2009)

Hydrocephalus results from an imbalance between the intracranial cerebrospinal fluid (CSF) inflow and outflow. It is caused by obstruction of CSF circulation, inadequate absorption of CSF, or (rarely) by overproduction of the CSF.

The most common mechanism of hydrocephalus is anatomic or functional obstruction to CSF flow (known as obstructive, or non-communicating hydrocephalus). The obstruction occurs at the foramen of Monro, the aqueduct of Sylvius, or the fourth ventricle and its outlets. Dilatation of the ventricular system occurs proximal to the obstruction. The ventricle just proximal to the obstruction usually dilates most prominently.

Impaired absorption Less commonly cause hydrocephalus due to inflammation of the subarachnoid villi, but also may be caused by impaired CSF absorption. The radiographic hallmark of communicating hydrocephalus is dilation of the entire ventricular system, including the fourth ventricle.

Excessive production of CSF is a rare cause of hydrocephalus. This condition may occur with a functional choroid plexus papilloma. It leads to enlargement of the entire ventricular system and the subarachnoid spaces, with a radiographic appearance that is similar to communicating hydrocephalus from other causes. (Yasuda et al., 2002)
Symptoms of hydrocephalus are nonspecific and independent of the etiology. Symptoms in infants include Poor feeding, Irritability, Reduced activity, Vomiting. The mechanism of the behavior changes is uncertain, but related in part to increased ICP. As the hydrocephalus worsens, midbrain and brainstem dysfunction may result in lethargy and drowsiness. Increased ICP in the posterior fossa often leads to nausea, vomiting, and decreased appetite. (Kirkpatrick et al., 1989)

Hydrocephalus is an important cause of macrocephaly in infants. Excessive head growth may be noted on serial measurements of head circumference plotted on growth curves. The sutures feel more widely split due to an enlarging head circumference with scalp veins appear dilated and prominent.

Compression of the third or sixth cranial nerve may result in extraocular muscle pareses leading to diplopia. Pressure on the midbrain may result in impairment of upward gaze which known as the setting-sun sign because of the appearance of the sclera visible above the iris. Funduscopic examination may reveal papilledema.

The spine of children should be carefully examined for stigmata of spina bifida suggestive of Chiari II malformation. As a result of stretching of the fibers from the motor cortex around the dilated ventricles may result in spasticity of the extremities, especially the legs. (Lopponen et al., 1996)

Accelerated pubertal development, as well as disturbed growth and fluid and electrolyte homeostasis, may result from pressure of the dilated third ventricle on the hypothalamus. (Lopponen et al., 1996)

The most effective treatment is surgical drainage, using a shunt or third ventriculostomy. Shunting allows CSF to flow from the ventricles into the right atrium of the heart (ventriculoatrial) or into the peritoneal cavity (ventriculoperitoneal) where it is absorbed, bypassing the site of mechanical or functional obstruction to absorption. In third ventriculostomy a perforation is made to connect the third ventricle to the subarachnoid space (Cinalli et al., 2011).
Methods of Ventricular Measurement:

Understanding the normal and abnormal anatomy of the ventricular system of the brain is helpful for clinicians, neurosurgeons, and radiologists in day-to-day clinical practice (Srijit and Shipra, 2007). Pneumoencephalography and ventriculography are the older techniques of visualizing the ventricular system by injecting air through lumbar puncture under local anaesthesia (Evans, 1942; Hahn and Rim, 1976; Meese et al., 1980).

Ventricular system can be studied by two-dimensional ultrasonic studies especially in children (Davies et al., 2000). Ultrasound is good for imaging the lateral ventricles but does not assess the posterior fossa well; the diagnostic accuracy of ultrasound also depends on the expertise of the user. As the anterior fontanelle closes, the ultrasound is no longer a useful diagnostic modality.

In recent years, Computed Tomography (CT) scan and Magnetic Resonance Imaging (MRI) have replaced the older methods of studying ventricular system (Sabattini et al., 1982).

CT is fast, reliable, and does not interfere with implanted medical devices. Head CT scanning usually can be accomplished without sedation. Disadvantages of CT scanning include radiation exposure (Brunetti et al., 2011).

MRI is generally the imaging modality of choice in patients with unexplained hydrocephalus, if it is readily available. MRI provides superior visualization of pathological processes in the cerebrospinal fluid (CSF) pathway, including CSF flow dynamics (Dinçer et al., 2011).

2.4 Head Circumference Measurement As A Screening Tool For Hydrocephalus

The most commonly used anthropometric measurements for the assessment of growth in child clinics are length/height, weight and head circumference (HC) or occipito-frontal circumference (Gale et al., 2006) reflecting general health and nutritional status of infants. HC can help us monitor the growth of the brain, because cognitive function, intracranial volume, and brain volume are closely related to the magnitude of HC (Coronado et al., 2012, Wilson & Williams, 2007).

The rate of increase in HC differs for different ages. During the first three months it is 3 cm per month, and then the anterior fontanel closes between 9-18 months. For
children between 4 and 6 years of age, HC growth is only one cm per year (Menounou et al., 2011).

The measurement of HC is an easy, non-invasive, and inexpensive method routinely included in the physical examination of infants and children. In infants, rapid increase in head size suggests the presence of hydrocephalus, while microcephalus can be associated with structural brain abnormalities or genetic syndromes (Ellis et al., 2012).

Macrocephaly (an abnormally large head) in the United States is defined as a head circumference above the 95th percentile (for normally distributed HC values corresponding to 1.64 standard deviations from the mean of gender and age specific controls) (Cole et al., 1994). WHO recommends using the more extreme 97th percentile (Borghi, 2006), and the 98th or 99.6th percentiles are proposed in the United Kingdom (Wright, 2011).

Routine measurement of HC in children is a diagnostic tool of utmost importance to achieve early detection and treatment, before permanent brain damage has occurred. In infants and small children, the CSF accumulation and enhanced intracranial pressure causes the skull to expand, and the condition can therefore be detected by a HC.

A study from Norway by Zah et al. about the efficacy of HC measurements in detection of paediatric hydrocephalus showed that 173 (58%) out of 298 neurosurgical pediatric patients were diagnosed with hydrocephalus using HC. Out of all cases, 138 (46%) were diagnosed because of an increased HC, which was the only symptom in 109 (79%) patients. (Zah & Wester, 2008). Illingworth et al. showed that early and routinely measuring of HC is also important in diagnosis of brain cancer (Illingworth & Lutz, 1965).

Various studies show that serial measurements of the head circumference are more important than a single measurement. It is known from other studies that the timing for completion of suture closure depends on the site of the suture, sex of the child and ethnic background (Menounou et al., 2011).
2.5 BRAIN VENTRICLES MEASUREMENT VALUES:

2.5.1 THE LATERAL VENTRICLES:

Garsia et al. showed that the lateral ventricular length (anterioposterior diameter) ranged from 2.16 to 4.5 cm in the left side while 2.03 to 3.26 cm in the left side in normal infant aged between 1-6 months. (Garsia et al., 2011). Another study in preterm infants showed that the anterior horn width to range from 1.3 in male to 1.22 in females among normal preterm babies. (Davis et al., 2000)

Huarhua et al. have studied the height of the frontal horn, obtaining the following mean values: 1.17 mm (SD ± 0.37) for male newborns), and 1.23 mm (SD ± 0.46) for female newborns; 1.27 mm (SD ± 0.62) for three month-old male infants, and 1.67 mm (SD ± 0.61) for three-month-old female infants. (Huarhua et al., 1996)

The mean VHR, in the study developed by Shah et al. it was 0.12 ± 0.052 in preterm newborns, and 0.12 ± 0.076 in full term newborns. The VHR increased from 0.14 ± 0.064 at the first month, to 0.17 ± 0.056 at the third month, stabilizing at this level up to the sixth month. (Shah et al., 1992)

Reeder et al. (1983) compared occipital horn measurements in premature infants and an occipital horn length exceeding 1.6 cm suggests intracranial pathology in preterms. Davies et al. (2000) reported much higher reference values for preterm neonates, with an upper limit of 2.47 cm.

Volumetric US and MRI measurements in neonates as well as children and adolescents also showed that left ventricular volumes tend to be larger than right ventricular volumes (Giedd et al., 1996). Asymmetry tends to be more pronounced in the occipital horns than in the anterior part of the lateral ventricle and side to side differences exceeding 5 mm have been described (Brouwer et al., 2010).

In a group of 65 hydrocephalus patients, Hahn and Rim, (1976), the frontal horn ratio varied from 0.34 to 0.78, with a mean of 44.8±0.78. Le May and Hochberg, (1979), found a mean frontal horn index of 0.5 in patients with obstructive hydrocephalus.
Hahn et al., (1977) studied the bifrontal index (Frontal horn ratio, FHR) of 388 normal brain scans and it was found to be $0.32 \pm 0.04$. Thus FHR, which can be interpreted as the maximum distance between the external margins of the frontal horns, is normally approximately one-third the width of the brain. Another study done by Park et al, (1990) in Korea with a larger sample size ($n=1000$) found a frontal horn index of $0.3\pm0.033$.

A Study of the changes in ventricular volume in hydrocephalic children following successful endoscopic third ventriculostomy (ETV) Using segmentation techniques found that in response to ETV, ventricular volume falls to a value lower than preoperatively but higher than the normalized value for age and sex with the volume stabilizing at 3–6 months (George et al., 2004). And this study showed the importance of ventricular volume measurement in the assessment of the effect of management.

### 2.5.2 THE THIRD VENTRICLE

A study from Brazil showed that the maximum width of the third ventricle was $5.54 \pm 0.35$ mm in boys and $4.98 \pm 0.34$ mm in girls. It was also noticed that the third ventricular width was higher in early childhood than in adolescence (Sari et al., 2014).

Gawler et al., (1976), Brinkman et al., (1982) and Soininen et al., (1982) found that the maximum width of the third ventricle in normal adult population had a mean of 0.46cm, 0.59cm and 0.92cm respectively with higher figures in males. D’Souza and Natekar (2007) found a width of 0.45cm in males compared to 0.39cm of females beyond the age of sixty years.

### 2.5.3 THE FOURTH VENTRICLE

One study utilizing ultrasound imaging showed that the means values for the fourth ventricle ranged from 4.59 mm in infants between 5 and 10 days of life to 6.52 mm in six month-old infants. (Garcia et. al 2011 ). Sari et al 2014 found the fourth ventricle width was to be lower in infancy in both
genders, being at minimum $8.10 \pm 0.19$ mm in girls and $8.72 \pm 0.45$ mm in boys less than one year age.

A study done by Gawler et al., (1976) found the greatest height of the fourth ventricle to be less than 1.2cm with a mean of 1.08cm. The width of the fourth ventricle as measured in later studies by Meese et al., (1980) and D’Souza and Natekar (2007) was found to be greater than the height in both sexes with males recording a significantly higher width (1.31cm), as compared to 1.21cm average of females. However, these studies found that there was a slight progression in the dimensions of the fourth ventricle with age.
Material and Methods

3-1 Methods: included all infant with congenital hydrocephalus whom diagnosed by paediatric department and sent for neurosurgery department in Gezira trauma centre. The head circumference was recorded from the occipital protuberance to the frontal area. Brain CT scan of the was done using Toshiba 64 slice CT scanner with requested slide quality of 1mm thickness using Alexion© software. The following measurement were obtained with the following protocol:

A. The image was taken with the infant in supine position, after application of head stabilizer under supervision of a trained nurse.
B. The image field included the whole skull including the base of skull and the first cervical vertebrae. No contrast was needed.
C. After acquisition and storage of image in transverse, coronal and sagittal view the following measurements were done using Alexion© software:

- The lateral ventricular length (A) and mid lateral ventricular body width (B) measured in transverse section in the slide just above the third ventricle with both ventricles separated by falx cerberi. Measured from the tip of the anterior horn to the tip of the posterior horn (picture 1). The right lateral ventricle was used for measurements to unify the measurements

![Picture 1: lateral ventricular measurements](image)
• The anterior (C) and posterior horn (D) width were measured at the same level as the distance between the medial edge of each horn to lateral wall of the horn.
• The bifrontal diameter (E) is measured as the distance measured between the tip of the two Anterior horns. The maximum diameter between the right and left cortices were also measured.
• The anterior (F) and posterior horn (G) length were measured at the same level as the tip of each horn to imaginary line formed between the medial edge of each horn to lateral wall of the horn.
• Lateral ventricular height (A) (picture 2) were measured in sagittal view in the slide behind the falx cerebri and both anterior and posterior horns were visible.

![Picture 2: measurement of ventricular height in sagittal plane](image)

• The Inferior horn width and height were measured in coronal section at the level at which the hippocampus was seen (The arrow) (picture 3)
Inferior Horn Width And Height Measurement In Coronal View

- Third ventricular length and width were measured in transverse section in a slide showing the entrance of interventricular foramina. (picture 4)

Picture 4: Third ventricular length and width were measured in transverse section
• Third (c) and fourth ventricular (E) height in sagittal section at the same level of (picture 2)
• fourth ventricular length and width (in transverse section just below the middle cerebellar peduncle).

3-2 Materials:

3-2-1 Study area:

The study was conducted in Gezira trauma centre located in Wad Medani receiving patients from west east and south sudan ,with a capacity of 40 beds. Facilities include emergency room, general ward, theatre, ICU, Labrotary and Radiology unit (containing x-ray, ultrasound and CT machienes). Specialized units include (General surgery, plastic surgery, neurosurgery and orthopaedics).

3-2-2 Study population:

All children with hydrocephalus in Gezira traumatology centre from January 2017 to June 2017.

3-2-3 Study design:

This is a prospective descriptive hospital based study was conducted between January 2017 to June 2017.

3-2-4 Inclusion criteria:

Any infants with congenital hydrocephalus in Gezira trauma centre from January 2017 to June 2017.

3-2-5 Exclusion criteria:

1- Patients more than 1 year.
2- Patient outside study period.
3- Patient diagnosed with communicating hydrocephalus.
3-2-6 Sampling technique:

Total coverage sample . including all infant with hydrocephalus between January 2017 to June 2017.

3-2-7 Data collection tools:

Data collection forms were constructed to collect data which include personal data, head circumference, biparietal diameter and ventricular measurements.

3-2-8 Data analysis:

Data was coded and fed in a computer to handle statistical and mathematical procedures, to display the analyzed data and present them graphically using SPSS software 22 (statistical package for social sciences) from IBM company. The mean, standard deviations and standard errors of all measurements were estimated and 95% confidence interval, both upper and lower, were calculated for all. The data was analysed by using ANOVA and student t-test for significance of differences in the ventricular measurements according to age, gender and head circumference.

3-2-9 Ethical consideration:

This research was agreed upon it by the research ethics committee of post graduate studies faculty (university of Gezira) with protection of the confidentiality of the data guaranteed. A written permission was obtained from Gazira Trauma Hospital administration. informed Verbal Consent was obtained from the legal guardian of the infants for filling the questionnaire, measuring the head circumference as well as viewing of CT scan results. The parents were informed that the participation in this research will not affect the outcome of management.
RESULTS

In this study 60 hydrocephalic infants were included who presented to the neurosurgery department in the interval between January to June 2017 all of them had non-communicating hydrocephalus. About Fifty seven percent of them were males with male to female ratio 3: 2. (Table 1)  

Table 1: Distribution of Hydrocephalic Infants By Age In Gezira Trauma Centre (n=60)

<table>
<thead>
<tr>
<th>Age(/months)</th>
<th>Frequency (percentage)</th>
<th>Total</th>
<th>Cumulative %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
<td></td>
</tr>
<tr>
<td>less than 1month</td>
<td>4(6.7%)</td>
<td>14(23.3%)</td>
<td>18(30%)</td>
</tr>
<tr>
<td>1-3months</td>
<td>15(25%)</td>
<td>3(5%)</td>
<td>18(30%)</td>
</tr>
<tr>
<td>&gt;3-6months</td>
<td>3(5%)</td>
<td>0(0%)</td>
<td>3(5%)</td>
</tr>
<tr>
<td>&gt;6-9months</td>
<td>6(10%)</td>
<td>9(15%)</td>
<td>15(25%)</td>
</tr>
<tr>
<td>&gt;9-12 months</td>
<td>6(10%)</td>
<td>0(0%)</td>
<td>6(10%)</td>
</tr>
<tr>
<td>Total</td>
<td>34(56.7%)</td>
<td>26(43.3%)</td>
<td>60(100%)</td>
</tr>
</tbody>
</table>

Most common age group of infants were those less than 6 months with incidence of (63%) (Table 1 )

The Mean head circumference was 46.2±6.2 cm .All the patients were above the 97th percentile of head circumference for age (figure 1). Male values were higher than female ones. There is significant statistical differences in head circumference According to gender (P value =0.00).
Figure 1: Comparison Between Head Circumference Among Hydrocephalic Infants In Gezira Trauma centre And The 97th Percentile Of Head Circumference for Age.

Rapid increase in Head circumference measurement was noticed after 6 months of age and there was significant statistical differences in Head Circumference according to age among hydrocephalic infants (P value:0.00) (Table 2).

Table 2: The Mean Head Circumference According To Age Among Hydrocephalic Patients In Gezira Trauma Centre (n=60)

<table>
<thead>
<tr>
<th>Age (months)</th>
<th>Mean (Cm)</th>
<th>Std. Deviation</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>less than 1 month</td>
<td>41.3</td>
<td>4.1</td>
<td></td>
</tr>
<tr>
<td>1-3 months</td>
<td>45.3</td>
<td>2.4</td>
<td>0.00</td>
</tr>
<tr>
<td>3-6 months</td>
<td>45.5</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>6-9 months</td>
<td>47.7</td>
<td>2.4</td>
<td></td>
</tr>
<tr>
<td>9-12 months</td>
<td>60.5</td>
<td>4.9</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>46.2</td>
<td>6.2</td>
<td></td>
</tr>
</tbody>
</table>

The study group had a mean lateral ventricular length , width and height of 9.7±3.7, 3.5±2,and 3.1±2.3 cm respectively. The mean values of lateral ventricular measurements were found to be higher in male group compared with female group. The study showed that the lateral ventricular
length width and height had significant statistical differences according to gender (Table 3)

Table 3: The Correlation Between The Lateral Ventricular Dimensions in (CM) And Gender among 60 Hydrocephalic Infants in Gezira trauma Centre

<table>
<thead>
<tr>
<th>Type of measurement</th>
<th>Site of measurement</th>
<th>Male Mean (Cm)</th>
<th>Female Mean (Cm)</th>
<th>P.value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>Lateral ventricle</td>
<td>10.6</td>
<td>8.2</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>Anterior horn</td>
<td>3.4</td>
<td>2.8</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td>Posterior horn</td>
<td>3.6</td>
<td>3.4</td>
<td>0.00</td>
</tr>
<tr>
<td>Width</td>
<td>Lateral ventricle body</td>
<td>3.9</td>
<td>2.7</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>Anterior horn</td>
<td>3.1</td>
<td>2.9</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Posterior horn</td>
<td>3.8</td>
<td>3.7</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>Inferior horn</td>
<td>2.8</td>
<td>2.3</td>
<td>0.00</td>
</tr>
<tr>
<td>Height</td>
<td>Lateral ventricle</td>
<td>3.4</td>
<td>2.6</td>
<td>0.029</td>
</tr>
<tr>
<td></td>
<td>Inferior horn</td>
<td>1.7</td>
<td>1.9</td>
<td>0.005</td>
</tr>
</tbody>
</table>

The lateral ventricular length width and height values showed rapid increase after the age of 6 months more obviously seen in the values of the lateral ventricular length. The study showed that the lateral ventricular length width and height had significant statistical differences according to Age (p value < 0.05). (Table 4)
Table 4: Correlation Between The Lateral Ventricular Dimensions In (Cm) And Age In Months Among 60 Hydrocephalic Infants In Gezira Trauma Centre

<table>
<thead>
<tr>
<th>Type of measurement</th>
<th>Site of measurement</th>
<th>Age (months)</th>
<th>P.value</th>
<th>Person's correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&lt;1</td>
<td>1-3</td>
<td>&gt;3 to 6</td>
</tr>
<tr>
<td>Length</td>
<td>Lateral ventricle</td>
<td>6.2</td>
<td>7.6</td>
<td>7.7</td>
</tr>
<tr>
<td></td>
<td>Anterior horn</td>
<td>1.9</td>
<td>3.35</td>
<td>3.44</td>
</tr>
<tr>
<td></td>
<td>Posterior horn</td>
<td>2.39</td>
<td>3.93</td>
<td>4.1</td>
</tr>
<tr>
<td>Width</td>
<td>Anterior horn</td>
<td>2.04</td>
<td>3.9</td>
<td>4.47</td>
</tr>
<tr>
<td></td>
<td>Posterior horn</td>
<td>2.8</td>
<td>3.5</td>
<td>3.3</td>
</tr>
<tr>
<td></td>
<td>Inferior horn</td>
<td>1.42</td>
<td>2.64</td>
<td>2.8</td>
</tr>
<tr>
<td>Height</td>
<td>Lateral ventricle</td>
<td>2.6</td>
<td>2.56</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Inferior horn</td>
<td>1.4</td>
<td>2.6</td>
<td>3.2</td>
</tr>
</tbody>
</table>

When lateral ventricular dimensions were plotted against head circumference it was noticed that the length was slowly rising until the head circumference value reach more than 50cm as rapid rise was recorded peaking at 15.85 cm .The same applied in lateral ventricular width and height as those volume were static below 50cm of head circumference .The study showed significant correlation (P value<0.05). (figure 2)
The study group had a mean anterior horn width of 3.0±1.2 and length of 3.2±1.7 cm. The mean anterior horn width was higher in male (3.1±0.9 Vs 2.9±1.4) cm. It was noticed that head circumference changes directly reflected changes in the anterior horn width more than length. Person's correlation was significant between age and lateral ventricular body length, height, and width. Person's correlation coefficient was significant between head circumference and lateral ventricular body length (0.37), height (0.4), and width (0.52). The study showed that the mean anterior horn measurements correlated with age (Table 4), gender (Table 3) and Head circumference (figure 3).

Figure 3: The Correlation Between The Anterior Horn Measurements in (Cm) And Head Circumference in Cm Among 60 Hydrocephalic Infants in Gezira Trauma Centre (P value=0.00) (AHL: Anterior horn length, AHW: anterior horn Width)
The mean anterior horn index the greatest distance between the tips of the frontal horns divided by the first transverse diameter of the brain along the same level was found to be 0.58±0.31 (Normal<0.3). The anterior horn index reflected the severity of hydrocephalus. Person's correlation coefficient showed correlation between head circumference and Anterior horn index(0.43) as shown in (figure4).

![Figure 4: The Correlation Between The Anterior Horn Index And Head Circumference in Cm Among 60 Hydrocephalic Infants in Gezira Trauma Centre (P value=0.00)](image)

Regarding the measurement of posterior horn width of 3.8± 2.1 cm and length of 3.5±1.9 cm. The study showed that the mean posterior horn measurements correlated with Head circumference (figure 5), gender (Table 3) and age (Table 4). Person's correlation coefficient was weekly significant between head circumference and posterior horn length(0.2) and width(0.3).

![Figure 5: The Correlation Between The Posterior Horn Measurements And Head Circumference In (Cm)among 60 Hydrocephalic Infants in](image)
**Gezira Trauma Centre (P value=0.00)** (PHL: posterior horn length, PHW: Posterior horn Width)

The measured Inferior horn mean width was 2.94 ±1.8 cm while inferior horn height of 1.7±1.1 cm. The study showed that the mean inferior horn height was larger in female group while the width was larger in male group. Figure 6 showed that inferior horn width was affected more than inferior horn height as the width showed progressive enlargement while the height appeared more static. The study showed that the mean inferior horn measurements correlated with both Head circumference (Figure 6), gender (Table 3) and age (Table 4). (P value<0.05). Person's correlation coefficient was significant between head circumference and posterior horn height (0.35) and width(0.4).

![Figure 6: The Correlation Between The Inferior Horn Measurements And Head Circumference In (Cm) Among 60 Hydrocephalic Infants in Gezira Trauma Centre. (P value=0.00).](image)

The third ventricle mean length, width and height of (1.7±1.0, 2.1±1.7, 1.7±0.6) cm respectively. All the measurements of the third ventricle were larger in males except mean third ventricular width which was higher in female (2.19±1.4 Vs...
The study showed that the mean third ventricular measurements correlated with gender (p value <0.05). (Table 5).

Table 5: The Correlation of The Third and The fourth Ventricular Measurements In Cm and Gender Among 60 Hydrocephalic Infants in Gezira Trauma Centre

<table>
<thead>
<tr>
<th>Type of measurement</th>
<th>Site of measurement</th>
<th>Male Mean (Cm)</th>
<th>Female Mean (Cm)</th>
<th>P.value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>Third ventricle</td>
<td>1.82</td>
<td>1.52</td>
<td>0.002</td>
</tr>
<tr>
<td></td>
<td>Fourth ventricle</td>
<td>2.03</td>
<td>1.35</td>
<td>0.003</td>
</tr>
<tr>
<td>Width</td>
<td>Third ventricle</td>
<td>2.03</td>
<td>2.19</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Fourth ventricle</td>
<td>1.89</td>
<td>1.3</td>
<td>0.01</td>
</tr>
<tr>
<td>Height</td>
<td>Third ventricle</td>
<td>1.73</td>
<td>1.68</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>Fourth ventricle</td>
<td>1.78</td>
<td>1.53</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Table 6: The Correlation of The third and the fourth Ventricular Measurements In Cm and Age in months Among 60 Hydrocephalic Infants in Gezira Trauma Centre

<table>
<thead>
<tr>
<th>Type of measurement</th>
<th>Site of measurement</th>
<th>Mean value (Cm) for Age (months)</th>
<th>P.value</th>
<th>Person's correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&lt;1</td>
<td>1-3</td>
<td>&gt;3 – 6</td>
</tr>
<tr>
<td>Length</td>
<td>Third ventricle</td>
<td>1.05</td>
<td>1.3</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>Fourth ventricle</td>
<td>1.9</td>
<td>1.75</td>
<td>1.8</td>
</tr>
<tr>
<td>Width</td>
<td>Third ventricle</td>
<td>1.33</td>
<td>1.34</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>Fourth ventricle</td>
<td>1.39</td>
<td>1.2</td>
<td>1.5</td>
</tr>
<tr>
<td>Height</td>
<td>Third ventricle</td>
<td>1.7</td>
<td>1.5</td>
<td>1.83</td>
</tr>
<tr>
<td></td>
<td>Fourth ventricle</td>
<td>1.63</td>
<td>1.64</td>
<td>1.67</td>
</tr>
</tbody>
</table>

The third ventricle mean length, width and height was found to correlate with age in the study group with rapid rise in the measurement after the age of 6 month. The effect of age on third ventricular dimensions was significant statistically (< 0.05).
person correlation coefficient between age and head circumference was significant as in (table 6).

When comparing the third ventricle dimensions according to head circumference (Figure 7) they were found to correlate with age as the curve went upward with the increase of head circumference. The study showed that the mean third ventricular measurements correlated with gender (p value <0.05). Person's correlation coefficient was significant between head circumference and third ventricle length(0.6), height(0.25) and width(0.48).

![Graph showing correlation between head circumference and third ventricle measurements](image)

<table>
<thead>
<tr>
<th>Measurement</th>
<th>TVH</th>
<th>TVW</th>
<th>TVL</th>
</tr>
</thead>
<tbody>
<tr>
<td>P.Value</td>
<td>0.00</td>
<td>0.00</td>
<td>0.001</td>
</tr>
</tbody>
</table>

**Figure 7:** The Correlation Between The Third Ventricle Measurements And Head Circumference In (CM) Among 60 Hydrocephalic Infants in Gezira Trauma Centre. The Table Above Shows The Statistical Differences IN The Third Ventricle Dimensions According To Head Circumference (TVH: Third ventricular height, TVW: Third Ventricular Width, TVL: Third Ventricular Length)

The fourth ventricle measurements had a mean length, width and height of (1.6±1.2, 1.7±1.4, 1.6±1.2) cm respectively. The study showed that was significant statistical differences in the fourth ventricular measurements according to gender and males had larger fourth ventricle measurements (Table 6). All measurements correlated with Age except the fourth ventricular length (P value =0.05).
According to head circumference we found that the curves of fourth ventricle measurements increased from less than 40cm to head circumference group of 40-45cm and then it decrease gradually afterward and then reach near the baseline. There was no significant statistical differences in the fourth ventricular measurements according to Head circumference (P value >0.05)(figure 8). Person's correlation coefficient was negative between head circumference and fourth ventricle length(-0.175), height(-0.16) and width(-0.107).

![Graph showing the correlation between fourth ventricular measurements and head circumference.](image)

<table>
<thead>
<tr>
<th>Measurement</th>
<th>FVH</th>
<th>FVW</th>
<th>FVL</th>
</tr>
</thead>
<tbody>
<tr>
<td>P.Value</td>
<td>0.930</td>
<td>0.998</td>
<td>0.058</td>
</tr>
</tbody>
</table>

Figure 8: The correlation between the Fourth Ventricular measurements and head circumference Among 60 Hydrocephalic Infants in Gezira Trauma Centre. The Table Above Shows The Statistical Differences IN The fourth Ventricle Dimensions According To Head Circumference (FVH: Fourth ventricular height, FVW: Fourth Ventricular Width, FVL: Fourth Ventricular Length)
DISCUSSION

5-1: DEMOGRAPHIC DATA:

This study included 60 hydrocephalic infants who presented to the neurosurgery department, Gezira Trauma centre in the period between January and June 2017. All the infants underwent brain CT scan as part of diagnostic process.

Head circumference is one of the most commonly used anthropometric measurements for the assessment of growth, nutritional status as well as intracranial pathologies (Gale et al. 2006). The mean head circumference measurement among study group was 46.2±6.2 cm and that agreed with Abd Elmoniem et al., (2015) study as most of the infants (50%) had a head circumference between (46-55) cm.

When head circumference values were plotted against age in comparison to 97th centile of WHO head circumference for age chart a significant correlation between age and head circumference in infants with hydrocephalus was noticed (P value >0.05). (WHO, 2018)

It is also noticed that male group had high mean value of head circumference compared to female group and that agreed with charts for head circumference by WHO. There was significant differences in head circumference according to gender (P value=0.001) (WHO, 2018). Further studies for explanation is required.

5-2 LATERAL VENTRICULAR MEASUREMENTS

This study agreed with previous studies comparing the anterior horns width with age among normal individuals by Hahn and Rim (1976) Gyldensted (1977), Haug, (1977), and Wolpert (1977).

It was noticed that the anterior horn measurements were affected more than the posterior and inferior horn which reflect the effect of hydrocephalus on frontal lobe namely the effect on personality, cognitive and motor development function as most of the infants complain of poor feeding, Irritability, Reduced activity, (Kirkpatrick et al., 1989).

The mean anterior horn index was found to be 0.58 (Ranging from 0.45-0.6) and this value was near twice the ratio in previous studies done by Hahn et al., (1977), Park et al., (1990) and Celik et al., (1995). This ratio was within the range of Hahn and Rim, (1976), study (0.34 to 0.78), with a mean of 44.8±0.78 in patients with obstructive Hydrocephalus. And also agree with Le May and Hochberg, (1979),
who found a mean frontal horn index of 0.5 in patients with obstructive hydrocephalus.

There was significant differences in AHI according to head circumference (P value=0.00), to Age (P value=0.031) and gender (P value=0.01). And these values agreed with Shah et al. study showing an increase in the AHI in normal individuals from 0.14 ± 0.064 cm at the first month, to 0.17 ± 0.056 cm at the third month.

Regarding the measurement of posterior horn width of 3.8 ± 2.1 cm and length of 3.5±1.9 cm with normal measurements of occipital horn length ranging from (1.6 -2.47 cm) (Reeder et al. 1983, Davis 2000). There was significant differences in the length and width of the posterior horn according to head circumference, age and gender.

Regarding the measurement of Inferior horn mean width of 2.6 ±1.8 cm and height of 1.8±1.1 cm. The normal size of the inferior horns was estimated to be less than 0.2 cm. (Awasthi D et. al 2016). The degree of enlargement of inferior horn of the lateral ventricles will demarcate the degree of compression exerted on memory and intellectction areas like hippocampus and Amygdala. And this finding explained Laurance et.al study findings as 62% of surviving hydrocephalic infant population suffered from intellectual impairment (Laurance and Coates 1962). There was significant differences in the width and height of the inferior horn according to head circumference, age, gender and head circumference.

The study showed that the head circumference correlated with lateral ventricular dimensions, and change in head circumference was a good predictor of ventricular dilatation. These results agreed with Coronado et al., 2012, Wilson & Williams.,2007 showing that cognitive function, intracranial volume, and brain volume are closely related to the magnitude of head circumference.

5.3 THIRD VENTRICLE DIMENSIONS

The mean ventricular width of the current study (2.1±1.7 cm) is approximately 7 times that reported by Haug (1977) in general normal population (0.338 cm).

The mean ventricular width was higher in male compared to female groups. There was significant differences in third ventricular width according to gender (P value=0.01). The current findings were also in agreement with Studies by Gawler et
al., (1976), Brinkmann et al., (1982), Soininen et al., (1982) reported that the maximum width of the third ventricle in normal population had a mean of 0.46cm, 0.59cm and 0.92cm respectively with higher figures in males.

The third ventricle was also found to increase in size with age in this study (p value=0.031), and this result which was in line with Haug (1977) and Celik et al., (1995).

There was significant differences in third ventricular width according to head circumference (P value=0.00). And this reflect that head circumference was a good indicator for third ventricular dimensions changes.

5.4 FOURTH VENTRICLE DIMENSIONS

The fourth ventricle measurements had a mean length, width and height of (1.6±1.2, 1.7±1.4, 1.6±1.2) cm respectively. The results were higher in comparison with Garcia et. al study which showed that the normal means values for the fourth ventricle were the following: 0.46 cm in infants between (5-10) days of life to 0.65 cm in six month-old infants (Garcia et. al 2011). The study findings showed significant differences in fourth ventricular width and height in the hydrocephalic infant group according to age with p value of (0.00, and 0.003) respectively while no significant differences in the length of the fourth ventricle according age (p value=0.05).

Fourth ventricle width was generally found to be larger in males than in females, a finding which was statistically significant in fourth ventricular length, width and height with p value of (0.05, 0.00, and 0.03) respectively and this agree with others studies on fourth ventricular measurement by Gawler et al., (1976) and D’Souza and Natekar (2007).

There was no significant differences in fourth ventricular length, width and height according to head circumference with p value of (0.9, 0.058, and 0.998). And this result that the head circumference is not a good indicator of the fourth ventricular dimensions which may be attributed aqueduct stenosis in some hydrocephalic infants with non-communicating hydrocephalus and also due to the presence of Luschka and Magendie foramina which drain the fourth ventricle. (Waxman SG, 2000)
CONCLUSION

In conclusion this research studied the correlation between morphimetric measurements of brain ventricles and head circumference among hydrocephalic infants in Gazira Traumatology Centre between January and June 2017. It was found that head circumference could be a mirror to reflect the degree of dilatation of the lateral and third ventricles but cannot predict differences in the fourth ventricular measurements. Males had higher lateral, third and fourth ventricular measurements compared to females. There was significant statistical differences in the mean lateral, third and fourth measurements according to age except the fourth ventricular width.
RECOMMENDATION

The following was recommended by the study:

- The use of serial head circumferences measurement by health personnel for follow up of progression of hydrocephalus
- Further large scale case control study to confirm the sensitivity of head circumference in predicting ventricular dimensions.
- Further studies on the effect of hydrocephalus on cognitive and intellectual centres and their impact on psychomotor function.
- Early detection of hydrocephalus in perinatal period by medical personnel to reduce the effect of hydrocephalus on brain centers.
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The Correlation Between Morphimetric Measurements Of Brain Ventricles And Head Circumference Among Hydrocephalic Infants In Gazira Traumatology Centre Between January And June 2017

For partial fulfillment of M.S. in anatomy by student Mohamed Soud Mohamed

Part 1: Personal Data

1. serial Number

2. Age: in months.

3. sex: 1- Male 2- female

4. Head circumference: cm

5. Presence of Myelomeningocele : 1-yes 2- No

Part 2: Dimensions of the ventricles: in mm

6. Left lateral ventricle body: 1- length 2- width 3- hieght

7. Anterior horn: 1- width 2- hieght 3- bifontal index

8. posterior horn: 1- width 2- hieght

9. Inferior horn: 1- width 2- hieght

10. Third ventricle: 1- length 2- width 3- hieght

11. Fourth ventricle: 1- length 2- width 3- hieght

12. Aqueduct of Sylvius : Diameter mm

13. Biparital diameter