

**PATTERNS OF ROUTINE CRANIAL ULTRASOUND FINDINGS
AMONG PRETERM BABIES AT MOI TEACHING AND
REFERRAL HOSPITAL**

BY

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DECLARATION

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DEDICATION

I dedicate this work to my family, my lovely wife Judy Chepkemai, my children, Sulweh, Ryan and Mary.

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First, I give thanks to God almighty for life as well as this opportunity to give back to society. Secondly, I would whole-heartedly like to appreciate my parents for their encouragement and immense support. A special mention goes to my mother, The Late Mary Sala who always encouraged me to publish. I would also like to give my sincere appreciation to my supervisors, Prof. Joseph Abuya and Dr. W. Nalianya, for their rigorous guidance throughout the development and implementation of this study. I would also want to thank the Department members of Radiology and Imaging for the support given to me.

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LIST OF ABBREVIATIONS

ARDS	Acute respiratory distress syndrome.
BW	Birth Weight
CDC	Centre for Disease Control
CP	Cerebral Palsy
CRP	C-reactive Protein
CT	Computerized Tomography
CUS	Cranial ultrasound
EOS	Early Onset Sepsis
GA	Gestational age
GBS	Group B Streptococcus
GMH-IVH	Germinal matrix-intraventricular hemorrhage
HIE	Hypoxic Ischemic encephalopathy
HRIS	Health Records Information System
IREC	Institutional Research and Ethics Committee
IVH	Intraventricular Hemorrhage
LBW	Low Birth Weight
MRI	Magnetic Resonance Imaging
MTRH	Moi Teaching and Referral Hospital
NICU	Newborn Intensive Care Unit
PVL	Periventricular Leukomalacia

PPROM	Preterm premature rupture of the membranes
RDS	Respiratory Distress Syndrome
SVD	Spontaneous Vaginal Delivery
VM	Ventriculomegaly
WHO	World Health Organization

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DEFINITION OF TERMS

Acoustic window - the location/site for ultrasound probe placement for scanning.

Extremely Low Birth Weight (ELBW) – Birth weight less than 1500 grams

Hertz (Hz) - the SI unit of frequency, used to measure sound, equated to one cycle per second

Infant Mortality - death of a child before attaining the age of one year.

Low birth weight - birth weight of less than 2500 grams

Moi Teaching and Referral Hospital - a tertiary hospital located in Eldoret serving the larger western Kenya, Rift Valley and beyond.

Neonate - a baby aged 28 days and below.

Preterm - a baby born before full gestation, usually 37 weeks.

Weber (Wb) - is the SI unit of magnetic flux, a measure of the strength of a magnetic field

Tesla (T) - the SI unit of magnetic density equivalent to one weber per square meter ($1\text{T} = 1\text{Wb}/\text{m}^2$)

Transducer - part of an ultrasound probe that converts electrical energy into mechanical (sound) energy and back

Very Low Birth Weight – birth weight less than two thousand (2000) grams

ABSTRACT

Background: Preterm delivery and low birth weight are the number one cause of infant mortality. Incomplete development and sub-optimal physiological adjustments make them prone to vascular injuries in the brain like intraventricular haemorrhage, periventricular leukomalacia and others. Routine cranial ultrasound, done on day 3 or 4 of life, is recommended for any infant 32 weeks and below to guide management and outline prognosis. This is critical for detecting intracranial pathologies in preterm babies, which if undiagnosed, can lead to adverse neurodevelopmental outcomes. Cranial ultrasound is relatively inexpensive and uses non-ionising radiation. However, due to workload and other resource limitations, babies' access to routine cranial ultrasound is dependent on priority.

Objectives: To determine the findings of routine cranial ultrasound and the association between demographic factors and abnormal cranial ultrasonographic findings amongst preterm babies at the new-born unit of Moi Teaching and Referral Hospital.

Methods: A cross-sectional study was done between September 2023 and March 2024. The sample size calculated was 127. All preterm babies born at 37 weeks gestation and below were consecutively recruited and consented. Cranial ultrasound was done on day 3 or 4 by the principal investigator, their images stored, verified by the radiologist and the findings documented. An interviewer-administered questionnaire was used to collect and document information on socio-demographic data of the mother and clinical characteristics of the baby. Data entry and cleaning was done. Data was analysed using descriptive statistics, in means, median and standard deviation for numerical data and frequencies and proportions for categorical data. Bivariate analysis was done using chi square and Fisher's exact test to test for association between demographic factors and abnormal cranial ultrasound findings. Multivariate analysis was done to evaluate the factors associated with the outcomes.

Results: Out of 127 preterm babies enrolled, 54.3% (69) were female and 45.7% (58) were male. The mean gestational age was 29.5 ± 3.1 weeks. 41.7% (53) of the mothers had a parity of 2 and ≥ 3 was 39.4 (50). 55.1% (70) were between 28-32 weeks and 46.5% (59) weighed between 1000-1500 grams. 36.2% (46) had abnormal findings which included intracranial haemorrhage (23.6 %), ventriculomegaly (18.9%), periventricular leukomalacia and congenital anomalies each at (3.2%). Out of the 46, 40% (12) had grade II intraventricular haemorrhage, while 20% (6) had intracerebral haemorrhage. There was significant association between low gestational age (P value = 0.002), low birth weight (P <0.001), increased mothers' parity (P=0.024) with abnormal cranial ultrasound findings.

Conclusion: More than a third of the babies had abnormal cranial ultrasound findings, the commonest being intracranial haemorrhage followed by ventriculomegaly. The main type of haemorrhage was intraventricular followed by intracerebral. Low gestational age, low birth weight and increased mothers' parity was associated with abnormal cranial ultrasound findings but not as independent predictors.

Recommendations: Routine cranial ultrasound should be done for every preterm infant <32 weeks or <1500 grams.

CHAPTER ONE: BACKGROUND

1.1 Overview

This chapter contains introduction, problem statement, justification, research questions, study objectives, and study limitations.

1.2 Introduction/Background

Preterm birth is any delivery that happens before 37 weeks gestation. According to the (CDC, 2022), preterm birth and low birth weight which at most times occur together are ranked the number one cause of Infant Mortality. Infant mortality is the occurrence of a child's death before attaining the age of one year. These children lack full development of vital organs such as the lungs, brain, and liver whose development is usually not completed up until the last weeks of pregnancy.

According to gestational age, prematurity is classified into 3 main categories: less than 28 weeks - Extremely preterm, 28 weeks to 32 weeks - Very preterm and 32 weeks to 37 weeks - moderate to late preterm. (*Preterm Birth*, n.d.)

Preterm babies are therefore prone to developing several life-threatening complications in their first few days or weeks of life. They may have sequelae into their life in future such as learning disability, cerebral palsy, delayed milestones amongst others. (CDC, 2022)

Preterm birth often occurs concurrently with low birth weight and has a myriad of radiological diagnoses that can be picked up early to guide timely and accurate management as well as predict prognosis to a good extent. (Sauve, 2001). Amongst them the most common identifiable complications are ischemic and hemorrhagic injuries which often occur together. This is due to physiologic disruption of the developing vasculature in the developing brain.

There are long arteries in the developing brain derived from the Anterior, Middle, and posterior Cerebral arteries. Any limitation to blood supply for whichever reason can result in dysregulation of the physiologic balance within the brain's vascular system and result in hemorrhage. Other injuries may be sequelae of blood supply disruption such as non-hemorrhagic cerebral infarction, hydrocephalus, periventricular leukomalacia, or cystic lesions, like porencephaly. Though extremely rare, sustained white matter injuries may lead to porencephaly. (Sauve, 2001)

Germinal matrix-intraventricular hemorrhage (GM-IVH) is the most common abnormality detected on cranial ultrasound in preterm infants. It involves bleeding from the germinal matrix, which is a highly vascular area in the developing brain. GM-IVH is graded based on the extent of bleeding, from Grade I which refers to mild disease to Grade IV which refers to severe disease (Chao et al., 2006).

Periventricular leukomalacia (PVL) is a type of brain injury that involves the death of white matter cells in the region around the ventricles. It is often a result of prolonged vascular insult and can be the sequelae of GM-IVH. It is often associated with impaired brain development and can lead to cerebral palsy or other neurological complications (Sauve, 2001).

Ventriculomegaly refers to the enlargement of the brain's ventricles, which are the Cerebrospinal fluid-filled cavities. It refers to a condition where there is an accumulation of cerebrospinal fluid in the brain's ventricles either from impaired absorption, usually referred to as the communicating type, versus an obstruction of CSF outflow also referred to as the obstructive type (Locke et al., 2022).

Other cranial ultrasonographic findings may include congenital conditions such as subependymal cysts and choroid plexus cysts. Subependymal cysts are fluid-filled

cavities that develop near the ventricles. Subependymal cysts or may be congenital, which is also referred to as germinolytic, or they may be postnatally acquired post-hemorrhagic cysts. These congenital cysts may result from infection, ischemic injury, or hemorrhage. They are relatively common in preterm infants and are usually benign. Choroid plexus cysts are fluid-filled sacs that develop in the choroid plexus, which is the structure that produces cerebrospinal fluid. They are often transient and typically resolve on their own (Chuang et al., 2007).

On cranial ultrasound echogenic periventricular areas may also be identified. These are areas of increased echogenicity (brightness) in the white matter surrounding the ventricles. They may be a sign of developmental or structural abnormalities in the brain (Chuang et al., 2007).

Ultrasound is the preferred mode of diagnosis for intracranial pathologies in preterm babies. Its imaging is relatively inexpensive, portable, and widely available for quick diagnosis of intracranial pathologies and conditions. According to the principles of acoustic physics, sound scatters variably by different interfaces of materials with different properties. Depending on the varied densities of the various surfaces, sound is either absorbed, or refracted or reflected. (Rumack et al., 2011) When sound waves strike off different tissues, they reflect the sound back characteristically dependent on their tissue density and as a result their shape and consistency can be captured for analysis. A transducer and a computer are all that is needed for cranial ultrasound.

Cranial ultrasound is an imaging technique that uses sound waves of frequencies ranging between 7.5 to around 12 MHzs to produce good quality brain images. The most recommended transducer is a 7.5 - 8 MHzs mounted on a micro-curvilinear probe. This will give good resolution for deeper structures. For high resolution of lesions close to the surface a linear probe of frequencies up to 11-12 MHz can be used. (Ecury-

Goossen et al., 2015) It is commonly used in neonates mainly and infants of less than six months whose skull bones are yet to fuse thereby providing an 'acoustic window' that allows the sound waves to freely pass into and back from the brain.

The transducer is a key component in ultrasound technology, playing a crucial role in medical imaging. It emits high-frequency sound waves, typically in the range of 2 to 18 megahertz, into the skull and surrounding tissues. These sound waves travel through the body and bounce back, or echo, when they encounter different types of tissues, such as fluid, muscle, or bone.

The transducer captures these echoing sound waves and analyzes various characteristics, including pitch and loudness, as well as the time it takes for the waves to return. This information is crucial for generating detailed images of internal structures in real-time, allowing healthcare providers to visualize organs, blood flow, and other bodily functions.

The process is non-invasive and does not involve ionizing radiation, making it a safe option for patients, including pregnant women and infants. The resulting images can help diagnose a variety of conditions, monitor fetal development, and guide medical procedures. As technology advances, ultrasound imaging continues to improve in resolution and diagnostic capabilities, further enhancing its value in clinical settings (Caro-Dominguez et al., 2021).

There are two main types of cranial ultrasound: head ultrasound and transcranial Doppler ultrasound. Head ultrasound, also known as cranial ultrasound, is primarily used to create detailed images of the brain's structure in neonates. This non-invasive procedure is particularly valuable for early detection of conditions such as intraventricular hemorrhage (IVH), periventricular leukomalacia (PVL), and other

brain abnormalities. The ultrasound waves penetrate the soft fontanelles, or “soft spots,” in a newborn's skull, allowing for visualization of brain anatomy and pathology. This technique is crucial in monitoring premature infants who are at higher risk for neurological complications. The real-time imaging capability of head ultrasound enables clinicians to make timely decisions regarding further interventions or treatments.

Transcranial Doppler (TCD) ultrasound, on the other hand, focuses on evaluating cerebral blood flow dynamics. This technique measures the velocity and direction of blood flow through major cerebral arteries, such as the middle cerebral artery and the anterior cerebral artery. By utilizing high-frequency sound waves, TCD provides information on blood flow patterns and can identify conditions such as vasospasm, which is critical in managing patients with stroke or other vascular abnormalities.

The ability to monitor cerebral blood flow in real-time is particularly beneficial in critically ill neonates, as it helps assess the risk of ischemia or hemorrhage. TCD is also useful in studying the effects of various treatments on cerebral hemodynamics, offering insights into the overall health of the brain.

Together, head ultrasound and transcranial Doppler ultrasound provide a comprehensive understanding of both structural and functional aspects of neonatal brain health. These tools are invaluable in the early detection and management of neurological issues, ultimately contributing to improved outcomes for vulnerable infants.

Doppler ultrasound is a specialized imaging technique that utilizes the Doppler effect to assess blood flow within the body's vessels. This method is instrumental in evaluating

various cardiovascular conditions and provides critical insights into hemodynamics by measuring both the direction and velocity of blood flow.

When sound waves emitted by the transducer encounter moving blood cells, they experience a change in frequency, which is known as the Doppler effect. If blood cells are moving towards the transducer, the frequency of the returning sound waves increases, resulting in a higher pitch. Conversely, if the blood cells are moving away, the frequency decreases, leading to a lower pitch. This shift in frequency is crucial for determining the speed and direction of blood flow.

The changes in pitch, along with the time it takes for the sound waves to return, are captured and displayed on a graph called a Doppler waveform. This graph illustrates various parameters, including the velocity of blood flow over time. Medical professionals interpret the patterns in these waveforms to assess the hemodynamic status of the patient. A normal waveform displays a characteristic pattern, while abnormalities may indicate conditions such as stenosis (narrowing of blood vessels) or turbulent flow.

Images generated by Doppler ultrasound are based on three primary characteristics of the sound signal: amplitude, frequency, and the time taken for the sound waves to return to the transducer. Amplitude refers to the strength of the returning signal, which can indicate the volume of blood flow. Frequency is directly related to the velocity of blood flow; higher velocities produce higher frequencies and vice versa. Time is crucial for calculating the distance the sound waves have traveled, helping to create a spatial representation of blood flow within the vessels.

This multifaceted approach allows for the visualization of blood flow dynamics in real-time, making Doppler ultrasound a vital tool in both diagnostic and therapeutic settings.

It is widely used in cardiology, obstetrics, and vascular medicine to monitor conditions such as fetal development, peripheral vascular disease, and cardiac function, ultimately enhancing the overall understanding of patient health.

Radiologists use cranial sonography to evaluate commonly occurring congenital abnormalities in neonates and preterm babies. It is used to routinely check and follow up brain maturation in preterm babies. Screening for brain hemorrhage, hydrocephalus, tumors, and possible infections of the brain is also indicated. Doppler sonography is used primarily to evaluate conditions affecting blood flow to the brain and to check for possibilities of stroke in sickle cell patients following blood blockage. (Milla SS, et al., 2020).

Other imaging techniques useful for imaging neonates alongside cranial ultrasound are computed tomography (CT), magnetic resonance imaging (MRI), and X-rays. Magnetic Resonance Imaging produces three-dimensional, highly detailed images of the body without using ionizing radiation. It is however available only at tertiary level hospitals in Kenya. The Moi Teaching and Referral Hospital (MTRH) based in Eldoret Kenya, has two machines: one machine of magnetic strength 0.3 Tesla and another of 1.5 Tesla. In Kenya as well as many other sub-Saharan countries in Africa, the cost implication leaves out most of the beneficiaries who may need MRI. (Anazodo et al., 2022).

Most preterm babies have severe illness requiring Intensive Care or High Dependency level of care and may have technical difficulty being wheeled to the Magnetom for imaging. Also, there are some challenges such as motion in babies that reduce the quality of images by creating artifacts as well as the time-consuming aspect. MRI provides better characterization of White Matter (WM) lesions but interpretation in preterm babies is not as straightforward as compared to adults. The optimal timings in terms of gestational age still have little literature around it. (Plaisier et al., 2015)

1.2 Problem statement

Globally, there are approximately 14.8 million preterm births each year (Perin et al., 2022). Prematurity has become a leading cause of death among children under the age of five, highlighting a significant public health concern. In sub-Saharan Africa, the situation is particularly dire, as nearly half of the children born before 32 weeks of gestation do not survive. This alarming statistic can be largely attributed to several factors, including limited knowledge about neonatal care and inadequate access to essential resources such as warmth and treatment for infections. Many of these factors are preventable, underscoring the urgent need for improved healthcare interventions and education to better support the survival and health of these vulnerable infants.

Preterm birth occurs in approximately 1 out of every 10 live births in the United States, as reported by the CDC. This statistic means that nearly 10 percent of all live births are classified as preterm, highlighting a significant public health issue. There is a notable predominance of preterm births among African American infants compared to their White and Hispanic counterparts, indicating disparities in maternal health and access to care. Complications arising from preterm birth and its associated sequelae contribute to the tragic deaths of about 1 million children before they reach the age of five each year. This alarming figure underscores the urgent need for effective interventions and healthcare strategies to improve outcomes for both preterm infants and their families (Walani, 2020).

Preterm delivery often results in a range of complications primarily due to vascular changes that can lead to either ischemia, hemorrhage, or, in many cases, both occurring simultaneously. These vascular issues can trigger immediate complications such as Intraventricular Hemorrhage (IVH) and Ventriculomegaly, conditions that require careful monitoring and intervention. Additionally, the impact of these complications

extends beyond the immediate neonatal period, as they can have long-term implications for the growth and development of the child. Specifically, these complications can significantly affect neurodevelopmental milestones, which are crucial for the child's overall cognitive and physical development. As a result, addressing these issues early on is essential to improving outcomes for preterm infants and supporting their long-term health and development (Sauve, 2001).

Early cranial ultrasound screening is critical for detecting intraventricular hemorrhage (IVH) and other brain injuries in preterm babies, which can lead to adverse neurodevelopmental outcomes if left undiagnosed and untreated (Mukherjee, 2019). The timely identification of these conditions allows for early intervention, which can significantly improve long-term outcomes. However, delays in access to this vital diagnostic tool can hinder timely diagnosis and management, exacerbating the risk of long-term disabilities (Papile et al., 2020).

In Kenya and other African countries, healthcare infrastructure often faces significant challenges, including limited availability of advanced diagnostic equipment such as ultrasound machines. A study by Musoke and Mbonye (2013) highlights that many neonatal units in sub-Saharan Africa lack the necessary resources to perform timely cranial ultrasounds. This lack of access delays diagnosis, leaving preterm babies vulnerable to complications such as hydrocephalus and periventricular leukomalacia, which require early detection and management to prevent severe neurodevelopmental impairments (Musoke & Mbonye, 2013).

The situation is compounded by a shortage of trained healthcare professionals capable of performing and interpreting cranial ultrasounds. In many African countries, there is a significant gap in specialized neonatal care training, which further delays the implementation of appropriate diagnostic procedures (Ezeaka et al., 2014). This skills

gap contributes to the delayed diagnosis and treatment of brain injuries in preterm babies, potentially leading to increased morbidity and mortality rates among this vulnerable population.

Globally, similar issues are observed, albeit to varying degrees depending on the region's healthcare infrastructure and resource availability. In low- and middle-income countries, the lack of access to advanced diagnostic tools is a common barrier to effective neonatal care. Delays in cranial ultrasounds in these settings often result from logistical challenges, including equipment shortages, inadequate maintenance, and insufficient training of healthcare providers (Vollmer et al., 2017). Consequently, preterm babies in these regions face a higher risk of undiagnosed brain injuries and subsequent neurodevelopmental delays.

Addressing these challenges requires concerted efforts to improve healthcare infrastructure, increase the availability of diagnostic equipment, and enhance the training of healthcare professionals in neonatal care. In Kenya and other African countries, initiatives aimed at strengthening healthcare systems and increasing investment in neonatal care resources are essential. Global health organizations and governments must prioritize these efforts to ensure that all preterm babies receive the timely diagnostic services they need for optimal neurodevelopmental outcomes (Kinuthia et al., 2019).

The cranial ultrasound is a powerful diagnostic tool in terms of diagnosis of preterm related conditions. It is, however, very user dependent and requires imparting the correct skills to every user. It would be best to have full implementation of the protocol at MTRH with some emphasis on defining to whom, when, how and by whom a cranial Ultrasound should be done to. This will allow timely diagnosis and as a result provide a channel of counselling the mothers on the possible outcomes early enough.

1.3 Justification

Prematurity often presents with low birth weight. (CDC 2022). Birth weight has been documented as the biggest prognostic factor for Preterm babies with lower birth weight being associated with higher mortality. In a study done at MTRH, the low birth weight (LBW) neonates had a mortality rate of 51.6%. None of the Extremely Low Birth Weight (ELBW) neonates survived. (Njuguna et al., 2014). Therefore, prematurity itself needs a keen eye from both the clinician and the radiologist to try and improve outcomes through early diagnosis.

Across Africa, the incidence of IVH and GMH in preterm babies varies, reflecting disparities in healthcare infrastructure and access to diagnostic tools like CUS. A multicenter study involving hospitals in South Africa, Nigeria, and Egypt reported an average IVH prevalence of 21%, with the highest rates observed in facilities with limited access to advanced neonatal care (Klein et al., 2015). This study highlighted the critical need for widespread implementation of CUS in African NICUs to improve early detection and management.

Gichuru et al. (2018) examined post-mortem findings in preterm babies, highlighting the prevalence of ICH and associated brain injuries. The study reported that approximately 30% of preterm babies exhibited some form of intracranial hemorrhage, often correlated with low birth weight and complications during delivery.

There have been very few studies touching neuroradiological cranial ultrasonographic features amongst the newborn. A study done at KNH dubbed “*The pattern of intracranial lesions detected by cranial sonography in infants*” was a maiden study done in 1993 that documented several patterns of lesions. It not only recommended that sonography should be the mainstay of diagnosing intracranial pathology before any

referral for CT or MRI but also recommended that more studies should follow to study patterns of Intracranial hemorrhage amongst preterm, term infants and older infants with severe neurologic disease. (Odhiambo, 1993)

A subsequent study was done in 2015 at MTRH comparing the cranial ultrasonographic findings and birthweight. (Moraa E. O., 2015) One of the unavailable things at the time was a portable Ultrasound machine whose acquisition was recommended. Due to logistical challenges, the study missed out on very sick babies who were either in NICU or had technical challenges being moved to the ultrasound room for review. These were such as those on phototherapy, ventilators, and more especially those in incubators who were circumstantially not included in the study.

This study, now with the available portable Ultrasound machine, focused on preterm babies and their unique lesions and sought to describe the lesions found as well as the clinical conditions they occur with.

Limited access to cranial ultrasounds for preterm babies poses a significant threat to their health and development. The timely diagnosis and management of brain injuries are critical for improving neurodevelopmental outcomes, and delays in accessing these services can have severe consequences. Efforts to improve healthcare infrastructure, increase the availability of diagnostic tools, and enhance healthcare provider training are essential steps toward addressing this critical issue and ensuring better outcomes for preterm babies worldwide.

1.4 Research Question

What are the findings of routine cranial ultrasounds done for preterm babies?

1.5 Study Objectives

1.5.1 Broad Objective

To describe the findings of routine Cranial Ultrasound findings on preterm babies at NBU MTRH and their clinical conditions.

1.5.2 Specific Objectives

1. To describe the routine Cranial Ultrasonographic patterns in preterm babies at the MTRH NBU.
2. To determine the demographic factors associated with the ultrasonographic findings.

CHAPTER TWO: LITERATURE REVIEW

2.1 Overview

This chapter looks to compare different literature and highlight more about the anatomy, physiology, various pathologies, and the clinical relevance including radiological diagnostics of brain conditions associated with Preterm babies.

2.2 Epidemiology

Birth that occurs before 37 completed gestation weeks with a live outcome is termed as Preterm birth. Worldwide, about 15 million babies are born before term. This translates to a global preterm birth rate of approximately 11%. Around 1 million children die due to complications surrounding preterm birth and its sequelae before attaining the age of 5 years. (Walani, 2020)

Walani et al continues to state that, birth before term leads as the number one cause of mortality among children under 5 years. For children under 5 it accounts for 18% of all deaths and amongst neonates it accounts for approximately 35%. The burden of Preterm birth rates and mortality varies in various geographical divides with a notable higher burden in lower- and middle-income economies. Sub-Saharan Africa and Southeast Asia have been identified to have a higher burden. (Lawn et al., 2010)

In a study done at MTRH in 2018, out of 175 babies 15.4% were neonates less than 28 weeks old, 30.9% 28- 31 weeks old and 53.7% between 32-37 weeks. 60.6% was the proportion that managed to get discharged with 29.6% for babies 28 weeks' gestation and younger, 50% for those born between 28-31 weeks survived until discharge and 75.5% of those older than 32 weeks were discharged from hospital. (Okwako et al., 2018)

In a study done by Alison Kent and others, 2549 neonates were sampled and amongst them 54.7% were male. The males were shown to have higher risk of grade III and IV IVH, severe sepsis, and had higher risk of requiring major surgery. This was noted to be only significant before 27 weeks gestation after which there were no differences amongst the genders. (Kent et al., 2012)

2.3 Preterm birth and its complications

Preterm birth can arise from a variety of causes, which can be categorized as either iatrogenic or non-iatrogenic. Iatrogenic factors often involve medical interventions, such as the induction of labor due to complications associated with conditions like gestational hypertension. In these cases, healthcare providers may determine that early delivery is necessary to protect the health of both the mother and the baby. However, it's important to note that most preterm births occur as a result of preterm labor, which can happen spontaneously without medical intervention. (Hashemi et. al., 2024)

In addition to iatrogenic causes, there are numerous other documented factors that contribute to the risk of preterm delivery. These factors can vary widely and may include multiple gestation pregnancies, which inherently carry a higher risk of complications. Another significant factor is chorioamnionitis, an infection of the amniotic fluid and membranes, which can trigger early labor. Low socioeconomic status is also associated with increased rates of preterm birth, as it can influence access to prenatal care and overall maternal health. (McRea et. al., 2008)

Other risk factors include intrauterine growth restriction (IUGR), which indicates that a baby is not growing properly in the womb, as well as maternal diabetes and advanced maternal age. Additionally, lifestyle choices such as the use of tobacco or marijuana during pregnancy can negatively impact fetal development and increase the risk of preterm delivery. Each of these factors plays a crucial role in understanding the

complexities surrounding preterm birth and highlights the importance of comprehensive prenatal care. (Padilla-Gomez et. al., 1992)

Preterm infants often face significant physiological challenges that hinder their ability to adapt to the extrauterine environment. Their underdeveloped organs and systems make it difficult for them to thrive outside the womb. This situation is particularly critical for babies classified as Extremely Low Birth Weight (ELBW), as they experience even higher rates of morbidity and mortality compared to their heavier counterparts. In a study conducted at MTRH, alarming findings were reported: none of the infants with ELBW survived. This highlights the severe risks associated with low birth weight and the urgent need for improved medical interventions and care strategies for these vulnerable populations (Njuguna et al., 2014). Addressing these challenges is crucial for enhancing outcomes for preterm infants and supporting their long-term health.

2.4 Cranial Ultrasonography

Cranial ultrasonography is indicated for preterm birth, neonates suspected of an intracranial pathology, a neonate who had a previously suspected anomaly on antenatal Ultrasound, or a newborn who had not been screened antenatally. It holds the benefit of being mobile and therefore can be easily used by the bedside. It uses non-ionizing radiation and requires not much prior preparation such as starvation or sedation. It can be easily used for following up now that serial scans can follow the initial one to assess progress over time (Steggerda and Meijler 2019). However, it is very highly user dependent and requires the user to be highly conversant with the techniques as well as the possible findings. (Rumack et al., 2011)

Regular cranial ultrasound examinations are essential for early detection, assessment of hemorrhage progression, and evaluation of potential complications such as hydrocephalus or cystic changes (Leviton et al., 2019).

Access to the brain is gained through the anterior fontanelle also known as the bregmatic fontanelle. The posterior fontanelle (lambdoid) can also be used as an acoustic window. (Caro-Domínguez et al., 2021) The mastoid fontanelle can also be used to visualize structures within the posterior fossa. (Fumagalli et al., 2020)

According to the MTRH neonatal Protocol, routine Cranial Ultrasonography should be done for babies 32 weeks and below or with weight of less than 1500 to rule out Intraventricular hemorrhage (IVH) and periventricular Leukomalacia (PVL). It recommends an Ultrasound scan on the 3rd day of life and subsequently on day 7. If necessitated the subsequent scan can be done earlier than the 7 days. Any Cranial Ultrasound that has abnormal findings will be followed up on a one or two weekly basis, then after discharge. (Nyandiko et al., 2015)

2.5 Transcranial Doppler

Transcranial Doppler (TCD) ultrasonography is a non-invasive diagnostic tool that has gained prominence in neonatal care. It measures cerebral blood flow velocities (CBFV) within the brain's major arteries, providing critical insights into cerebral hemodynamics in neonates. The following parameters can be measured on both sides (right and left sides) for paired vessels and one sided for the non-paired ones: peak systolic velocity (PSV), pulsatility index (PI) and resistivity index (RI). (Raju et. al., 1982)

Sudden changes or inadequate blood flow into the different brain regions may end up in insufficient delivery of glucose and oxygen. This may further lead to tissue damage and loss. (Lee, et al., 1995).

Transcranial doppler ultrasound is largely based on the principle of the “Doppler effect”. The principle guides the fact that, ultrasound waves emanating from the probe are transmitted into the blood vessel and reflected by the red blood cells in motion within the intracerebral vessels that will be moving either away or towards the direction of the probe. There is a frequency difference between the emitted waves as compared to the reflected waves. This difference is referred to as the “Doppler shift frequency”. It is directly proportional to the speed of the moving red blood cells which gives the blood flow velocity. Blood flow within the vessel is laminar, and therefore the Doppler signal obtained represents a combination of different Doppler frequency shifts. This forms a spectral display of the distribution of the velocities of individual red blood cells on the display screen (Purkayastha et al., 2012).

The cerebral vascular system is composed of several arteries that are accessible via ultrasound. The six main arteries which are accessed are derived from anterior and posterior circulation. The major arteries include anterior cerebral artery (ACA), middle cerebral artery (MCA), from the anterior circulation and posterior cerebral artery (PCA) from the posterior circulation. Other vessels include anterior choroidal artery (ACh) that is a branch of the internal carotid artery (ICA) directly, the basilar artery (BA) and the superior cerebellar artery that originate from the vertebral artery which gives the posterior circulation as well. (Courties et.al, 2015)

Pulsatility Index, which is the difference between the peak systolic flow and minimum diastolic flow velocity, divided by the mean velocity. $PI = (VS - VD) / TAMAX$ while, $RI = (VS - VD) / VS$. TAMAX is time average mean of maximal velocities, often known

as mean velocity. (VS) peak systolic velocity and (VD)end diastolic velocity (Kamel et al., 2023)

Transcranial doppler has become increasingly vital for assessing various neurological conditions, including intraventricular hemorrhage, periventricular leukomalacia, brain infections and hypoxic-ischemic encephalopathy in newborns. By offering real-time data on blood flow, Transcranial Doppler helps clinicians make informed decisions about the management and treatment of vulnerable neonatal patients just at the bedside. (Kamel et al., 2023)

Neonates, particularly preterm infants, are at high risk for cerebral complications due to the immaturity of their brain vasculature. Transcranial Doppler plays a crucial role in early diagnosis and intervention, potentially reducing the incidence and severity of long-term neurodevelopmental impairments. The ability to monitor cerebral blood flow non-invasively is especially valuable in neonates, where traditional methods such as direct intracranial pressure monitoring are not feasible or safe. (Raju et. al., 1982)

The frequency of use as well as timing of the transcranial doppler, together with the indications for investigation, and the influence of its findings on clinical practice in the PICU have been seldom illustrated in the world over. An international, web-based survey done by a team in North America, found that transcranial doppler was frequently used in North American pediatric neuro-critical care units. It was considered as a very useful guide when it comes to management of patients (Rollet-Cohen et al., 2021).

The use of Transcranial Doppler in neonates extends beyond diagnosis. It is also instrumental in monitoring the effectiveness of therapeutic interventions, such as therapeutic hypothermia in neonates with hypoxic-ischemic encephalopathy. Studies have shown that Transcranial Doppler can detect changes in cerebral perfusion

associated with cooling therapy, allowing for adjustments to treatment protocols in real-time. This dynamic capability makes Transcranial Doppler an essential tool in neonatal intensive care units (NICUs) for monitoring infants with hypoxic ischemic encephalopathy as well as other neurologic conditions (Liu et al., 2023).

A significant advantage of Transcranial Doppler in neonates is its ability to provide continuous, bedside monitoring without exposing the infant to radiation or the need for sedation. This safety profile is critical in the NICU setting, where neonates often require frequent monitoring (Kamel et al., 2023). Additionally, Transcranial Doppler is cost-effective and can be performed by trained personnel, making it accessible in various clinical settings, including resource-limited environments.

However, the interpretation of Transcranial Doppler results in neonates requires a deep understanding of neonatal cerebrovascular physiology. The variability in cerebral blood flow velocities due to factors such as gestational age, birth weight, and the presence of congenital heart anomalies like a patent ductus arteriosus (PDA) necessitates careful consideration when analyzing Transcranial Doppler data (Benders et al., 2015). Clinicians must be trained in both the technical aspects of Transcranial Doppler and the specific hemodynamic characteristics of neonates to ensure accurate diagnosis and management. (Raju et. al., 1982)

Recent advancements in Transcranial Doppler technology, including the development of high-frequency transducers, have improved the resolution and accuracy of measurements in neonates. These innovations allow for better visualization of smaller cerebral vessels, providing more detailed assessments of cerebral blood flow. As technology continues to evolve, Transcranial Doppler is likely to become even more integral to neonatal care. (Smyser et al., 2019)

Transcranial Doppler has also been utilized in the assessment of cerebral autoregulation in neonates, which refers to the brain's ability to maintain stable blood flow despite changes in systemic blood pressure. Disruptions in cerebral autoregulation are associated with adverse neurological outcomes. Transcranial Doppler offers a non-invasive method to evaluate this critical function, potentially guiding therapeutic strategies to protect the neonatal brain (Rollet-Cohen et al., 2021).

In addition to its diagnostic and monitoring capabilities, Transcranial Doppler has shown promise in research applications, particularly in studying the pathophysiology of neonatal brain injuries. For example, Transcranial Doppler has been used to explore the relationship between CBFV patterns and neurodevelopmental outcomes, contributing to a better understanding of how early cerebral hemodynamics influence long-term brain health (Ting et al., 2021).

Despite its many advantages, Transcranial Doppler is not without limitations. The technique is operator-dependent, meaning that the accuracy of the results can vary based on the skill and experience of the person performing the examination. Moreover, the interpretation of Transcranial Doppler data can be challenging due to the complex interplay of factors influencing cerebral blood flow in neonates. These challenges underscore the need for standardized training and protocols in the use of Transcranial Doppler in neonatal care. (Purkayastha et al., 2012)

The role of Transcranial Doppler in neonatology is further supported by its ability to detect early signs of cerebral vasospasm, a condition that can lead to ischemic brain injury if not promptly identified and treated. Cerebrovascular flow is a helpful biomarker in many cerebrovascular disorders in infants (Carr et al., 2021).

In cases of neonatal stroke, Transcranial Doppler has been used to identify alterations in cerebral blood flow that may indicate the presence of an occlusion or other vascular abnormalities. Early identification of such changes allows for rapid initiation of treatment, which is crucial in minimizing the extent of brain damage (Carr et al., 2021).

2.6 Ultrasonographic findings in preterm babies

The Canadian pediatric society in 2001 classified common ultrasound findings amongst preterm babies into three broad but cross-cutting categories: (Sauve, 2001)

- Isolated Germinal Matrix (GM) hemorrhage with or without IVH
- Echodensities and/or lucencies in parenchyma with or without GM and/or IVH
- Ventriculomegaly with or without GM and/or IVH

However, the parenchymal echodensities/lucencies category is broad and includes Periventricular Leukomalacia, Cranial Infections, and Hypoxic Ischemic Encephalopathy, among others.

2.6.1 Hemorrhage

Germinal matrix-intraventricular hemorrhage (GMH-IVH) is a frequently encountered pathology in the preterm neonates. This is especially so for those born with very low birth weight (VLBW) and before 32 weeks of gestation. The bleeding in the developing brain starts in the fragile capillary network of the subependymal germinal matrix. This disrupts the ependymal layer extending into lateral ventricle. GMH-IVH is commonly a precursor of neurodevelopmental challenges like post hemorrhagic hydrocephalus, epilepsy, cognitive impairment, cerebral palsy, and visual and hearing impairment. It accounts for a greater percentage of mortality in babies.

The germinal matrix, an anatomical structure only present in the fetus and in premature neonates, is an embryological developmental anatomical feature of the fetal brain. Pathology associated with the GM carries significant mortality and morbidity, and this

is because it is the most sensitive area of the fetal brain. Usually, the germinal matrix is notably identified between 8 weeks and 28 weeks of gestation. Anatomically, it is situated just lateral to the lateral ventricles. The germinal matrix is made up of a large cluster of fragile cells. These cells give rise to both neural and glial cells, and as a result, it contributes to grey matter. The germinal matrix can only be seen in premature babies less than 37 weeks and not in term babies. (Nadarajah et al., 2003).

Cells in the germinal matrix have been shown to have high metabolic activity. As a result, they have very high numbers of mitochondria and require high amounts of oxygen as well as nutrients. This makes them very sensitive to low oxygen states. The blood supply of the germinal matrix is derived from a mesh like capillary framework that is primitive and very fragile. This framework derives its arterial supply from the recurrent artery of Heubner and the lateral striate arteries. These are branches of the anterior cerebral artery and the middle cerebral artery. The germinal matrix is drained by the terminal vein which opens into the internal cerebral vein and eventually drains into the great vein of Gallen (Mukuria et al., 2018).

The primitive GM has very fragile vessels. This, combined with fluctuations in blood flow to the cerebrum due to low mean arterial pressure (MAP) and sub-optimal cerebral autoregulation, contribute to the pathogenesis of GMH-IVH. These result in rupture of vessels resulting in hemorrhage. The hemorrhage may be confined to the GM or may extend into the lateral ventricle. Initially, the bleeding is confined to the periventricular areas and is termed as periventricular hemorrhage (PVH). The increasing volume of blood may dissect into the adjacent lateral ventricles, if the bleeding persists, leading to intraventricular hemorrhage (Egesa et al., 2021).

The primary pathophysiological factor in intraventricular hemorrhage is the fragility of the germinal matrix, a network of blood vessels in the subventricular zone of the

developing brain. This matrix is particularly vulnerable to rupture due to its high density of immature and thin-walled capillaries. In preterm infants, these vessels are prone to rupture from fluctuations in blood pressure or changes in cerebral blood flow (Volpe, 2008). The germinal matrix is gradually replaced by mature brain tissue as gestation progresses, reducing the risk of IVH as the infant matures (Kuban et al., 2009).

There are several risk factors that contribute to the development of IVH, including: perinatal asphyxia, blood pressure changes, mechanical ventilation, and infection. The mechanisms of insults are varied, even though centered around perfusion.

Perinatal asphyxia, which is oxygen deprivation at birth, can cause hypoxic-ischemic injury, which compromises the stability of the germinal matrix vessels and increases the likelihood of hemorrhage (Batton, 2017).

Fluctuations in Blood Pressure has a sudden impact in perfusion due to fluctuating volumes. Sudden changes in systemic blood pressure can lead to unstable cerebral perfusion, exacerbating the risk of vessel rupture of the already fragile vessels (Yamamoto et al., 2021).

Mechanical Ventilation, which is a consequence of respiratory distress, a common presentation of preterm infants, also predisposes to subependymal germinal matrix vascular insults. The use of mechanical ventilation and positive pressure ventilation can affect cerebral blood flow dynamics, potentially contributing to IVH (Eryilmaz et al., 2020).

Intrauterine infection and systemic inflammation are associated with increased risk of IVH, possibly through effects on cerebral blood vessel stability and coagulation. Septic shock may also occur secondary to disseminated infection and decrease perfusion in

many key areas such as the brain, and in this case the germinal matrix. (Leviton et al., 2019).

Diagnosis of IVH typically involves neuroimaging techniques such as cranial ultrasound, which can detect the presence and extent of hemorrhage. Management strategies focus on minimizing risk factors through careful monitoring of blood pressure, optimizing respiratory support, and providing neuroprotective interventions, including antenatal corticosteroids and early postnatal care (Miller & Papile, 2021).

On Ultrasound they appear as echogenic regions near the caudothalamic groove and spread along the floor of the frontal horn of the lateral ventricles. The location of the caudo-thalamic groove, which is the landmark, sets it apart from the Choroid plexus which also appears echogenic. GM-IVH is noted anterior to the groove.

Ultrasonographic examination of IVH often begins with identifying subtle early changes in the germinal matrix and surrounding areas. In the early stages of IVH, ultrasound may show an echogenic (bright) area within the ventricles, corresponding to the presence of fresh blood. These early hemorrhages are often localized to the germinal matrix and can be seen as small echogenic foci in the lateral ventricles (Papile et al., 2014).

Chronic IVH can lead to the development of post-hemorrhagic ventricular dilatation (PHVD) or hydrocephalus, which can be monitored with follow-up ultrasounds. Chronic changes might include persistent ventricular enlargement and the presence of hemosiderin deposits, which appear as irregular echogenic areas in the brain parenchyma (Volpe, 2008).

Papile et al. and Volpe recommended grading systems that are the most widely accepted. Papile et al. developed a grading system based on the location as well as the severity of the hemorrhage.

- Grade I - restricted to the GM,
- Grade II - spread to the lateral ventricles but occupies less than fifty percent of the ventricles.
- Grade III- hemorrhage notably occupying more than half the volume (50 percent) of the ventricle and with ventriculomegaly.
- Grade IV - hemorrhage that extends to the nearby brain parenchyma.

Grade I and II are referred to as mild, while grades III and IV are referred to as severe GMH-IVH. (NCBI)

This grading is important for understanding the eventual outcomes of the baby. The prognosis is dependent on the extent of grade of the hemorrhage as well as whether hydrocephalus is present or not. Generally, for grade I and grade II hemorrhages, there is a fairly good outcome. According to Han R. et al., mortality rates are as follows 3.1% for grade I, 7.8% for grade II, 21.3% for grade III, and approximately 36.1% for grade IV (Han et al., 2018).

2.6.2 Periventricular Leukomalacia (PVL)

This is white matter injury in the periventricular regions. It has been documented to have a high likelihood of babies with PVL developing Cerebral palsy in future. It occurs more commonly in babies born less than 34 weeks. It occurs as a result of ischemia due to vascular changes at the periventricular areas. (Sauve, 2001)

Periventricular leukomalacia is a type of white matter injury commonly seen in premature infants, characterized by the destruction of white matter near the ventricles.

Ultrasonographic imaging reveals specific features associated with PVL, allowing clinicians to assess the extent of brain injury and plan appropriate interventions (Feller et al., 2014).

It may be staged according to timing as follows: Early, Sub-acute and Late periventricular leukomalacia. Early PVL involves necrosis of periventricular white matter. Subacute PVL is marked by formation of cysts within the white matter, while in late PVL, there is loss of parenchyma with ventriculomegaly. (Sauve, 2001)

In a publication by Chao and others in 2001, they graded PVL sonographic findings as follows: (Chao et al., 2006)

- Grade 1: notable periventricular echogenicity without any cyst usually lasting more than 7 days.
- Grade 2: echogenicity with resolution into small periventricular cysts.
- Grade 3: increased echogenicity in the periventricular region, which develop into extensive periventricular cysts commonly in the frontoparietal and occipital areas.
- Grade 4: increased echogenicity of the deep white matter in the periventricular region that developing into extensive subcortical cysts.

Early ultrasonographic findings in PVL often include echogenicity changes in the periventricular regions. Initially, these areas may appear as hyperechoic (bright) regions due to the presence of gliotic tissue and loss of normal white matter. The hyperechoic areas initially are centered in the periventricular area, around the peri trigonal region and antero-lateral to the frontal horns, usually less echogenic than the choroid plexus. Later they could develop cysts in those areas. (Agut et al., 2020)

As PVL progresses, these hyperechoic areas can become more pronounced and are often accompanied by cystic changes. These cysts are typically located near the ventricles and are indicative of necrosis and subsequent tissue loss (Rutherford, 2002).

The cystic changes observed in PVL are crucial for its diagnosis. On ultrasound, these cysts appear as well-defined, fluid-filled spaces adjacent to the ventricles. They appear thin walled, well defined anechoic lesions with posterior acoustic enhancement. The location of these cysts is typically periventricular, and their presence correlates with the degree of white matter damage. The size and number of cysts can vary, with larger and more numerous cysts generally indicating more severe white matter injury (Papile et al., 2004).

As PVL evolves, additional ultrasonographic features may include ventricular enlargement and cortical dysplasia. Ventricular enlargement, or hydrocephalus, occurs due to the loss of surrounding white matter and can be monitored using serial ultrasounds. Cortical dysplasia, or abnormal cortical development, may also be observed as irregularities in the brain's surface, which can be detected using high-resolution ultrasound techniques (Volpe, 2008).

Chronic PVL can lead to further complications, which are also identifiable through ultrasonography. These complications may include progressive cystic changes and development of abnormal calcifications. Calcifications, if present, appear as echogenic foci within the white matter on ultrasound and can be associated with long-term neurodevelopmental outcomes (Leviton et al., 2009). Serial imaging is important for tracking the progression of these changes over time.

Ultrasonographic evaluation of PVL is essential for both diagnosing and managing the condition. Regular cranial ultrasounds provide valuable information about the extent of

white matter injury and help guide clinical decision-making. Early detection of PVL-related changes can lead to better management strategies and improved long-term outcomes for affected infants (Biran et al., 2013).

2.6.3 Infections

Brain infections in neonates can present with various ultrasonographic features, depending on the type of infection and its stage. Ultrasonography is a key diagnostic tool in identifying these infections, especially in preterm or critically ill infants where other imaging modalities may be limited (Goh et al., 2017).

Cranial Ultrasound can detect anatomical changes that result from infection. Common brain infections include meningitis, encephalitis, and abscesses. The anatomical changes can be such as infarction from meningitis, and ventriculitis, which is diffuse echogenic ependymal lining in the lateral ventricle walls. Conditions such as viral infection, which is mostly congenital, and toxoplasmosis may have calcifications in the peri-ventricular area as well as the brain parenchyma or may have mineralizing lenticulostriate vasculopathy.

In the case of bacterial meningitis, ultrasonographic findings typically involve changes in the ventricles and surrounding brain structures. Initially, there will be mild diffuse increased reflectivity and thickening at the leptomeninges and the extra-axial spaces with resultant mildly compressed (slit-like) ventricles are noted. Later, bacterial meningitis often presents with ventricular enlargement due to associated hydrocephalus. This is due to increased intracranial pressure and reduced CSF reabsorption. Additionally, the presence of periventricular edema or increased echogenicity in the subarachnoid space can be observed. Widened interhemispheric fissures and effacement of sulci may also be seen. These changes reflect inflammation and fluid

accumulation, which are consistent with the disease's pathophysiology (Leviton et al., 2016).

Viral encephalitis, on ultrasound may show focal areas of increased echogenicity within the brain parenchyma, indicative of inflammatory changes and edema. In severe cases, areas of necrosis or cystic changes might be visible. The pattern of involvement typically includes the cortical and subcortical regions, which helps differentiate encephalitis from other types of brain infections (Klein et al., 2020). High-resolution ultrasound can also detect ventricular enlargement or abnormalities in brain structure associated with advanced encephalitis.

Brain abscesses can be identified on ultrasonography as well-defined, hypoechoic (dark) lesions with surrounding hyperemic zones and posterior acoustic enhancement. These lesions may have an irregular or lobulated appearance, reflecting the encapsulated pus and inflammatory response. The surrounding hyperemic zone is indicative of increased blood flow in the area due to the body's immune response to the infection (Goh et al., 2017). The presence of abscesses on ultrasound requires immediate medical attention to manage and drain the abscess if necessary.

Chronic infections or complications from initial infections, such as post-infectious cystic changes or calcifications, can also be visualized with ultrasound. These may appear as cystic lesions with varying echogenicity or as calcified foci in the brain parenchyma. Chronic sequelae from infections like meningitis or encephalitis often lead to long-term neurodevelopmental issues, and ongoing ultrasound monitoring is critical for assessing the extent of damage and guiding further management (Volpe, 2008).

2.6.4 Ventriculomegaly

Ultrasonographic evaluation of ventriculomegaly begins with measuring the size of the ventricles. The primary feature on ultrasound is the enlargement of the lateral ventricles, which can be quantified using measurements of the ventricular atria, the widest part of the ventricle. According to the guidelines, ventriculomegaly is generally defined when the atrial width exceeds 10 mm, with more severe cases showing progressively larger measurements. This dimension is the lateral ventricular diameter which is measured at the largest diameter across the atria on an axial plane. This measurement is critical for diagnosing and staging the severity of ventriculomegaly (Jansen et al., 2018).

In addition to ventricular enlargement, ultrasonography can reveal associated structural changes. For example, the presence of periventricular white matter abnormalities, such as echogenic foci or areas of increased echogenicity, may indicate damage or loss of brain tissue adjacent to the ventricles. These changes are often observed in conditions like periventricular leukomalacia or other forms of white matter injury. Identifying these associated changes helps in assessing the impact of ventriculomegaly on overall brain development. (Levy et al., 2014)

Ventriculomegaly may be classified as communicating or non-communicating. The non-communicating type usually has a disruption in the CSF outflow within the ventricular system whereas the communicating type may have other causes including blockage from outside of the ventricular system. It has variable causes which may be categorized broadly as follows:

- May occur together with congenital anomalies and syndromes.
- Increased CSF production or
- decreased absorption of CSF

- Blockage in CSF outflow

When ventriculomegaly is caused by obstruction, additional features may be evident. On ultrasound, obstructive hydrocephalus is typically associated with a triad of findings: ventricular enlargement, an intact cortical mantle, and a possible presence of a mass effect from the obstruction. This can include findings like an enlarged third ventricle and/or fourth ventricle, depending on the level and nature of the obstruction (Rutherford, 2002). Detailed evaluation of the ventricular system can help differentiate between obstructive and non-obstructive causes of ventriculomegaly.

Symptoms may not be apparent, but clinically it may present with increasing head circumference, bulging fontanelles and eventually neurologic symptoms and signs if not addressed.

Ultrasound reveals enlarged ventricles together with some level of parenchymal thinning that may vary. (Wylde & Watkinson, 2004)

In cases of chronic ventriculomegaly, ultrasonography may reveal further complications such as ventriculoperitoneal shunt placements or associated cortical atrophy. Long-standing ventricular enlargement often leads to thinning of the cortical mantle and possible formation of subdural collections. Ultrasound imaging can show these chronic changes and help monitor the effectiveness of interventions such as shunt placements or other therapeutic measures (Volpe, 2008).

Regular follow-up with cranial ultrasound is essential for monitoring the progression or resolution of ventriculomegaly. Serial imaging allows clinicians to track changes in ventricular size and brain structure over time, assess the effectiveness of treatment, and adjust management plans as needed. The ability to perform bedside ultrasonography is

particularly advantageous in the neonatal intensive care setting, where frequent monitoring is often required (Volpe, 2008).

2.6.6 Congenital Anomalies

There are many varied congenital anomalies usually picked in earlier ante-natal scans so the routine head ultrasound may be used to expound on an already existing diagnosis. It may also be useful for mothers who never attended Antenatal Care (ANC) or did attend but missed having a scan especially in low resource settings. The Ultrasonographic findings will be varied depending on the specific congenital anomaly.

Neural tube defects, including spina bifida and encephalocele, are also identifiable through cranial ultrasound. In cases of spina bifida, ultrasound may show a defect in the vertebral column and associated brain abnormalities, such as Chiari malformations. Encephalocele, which involves the herniation of brain tissue through a skull defect, appears as a protruding sac filled with cerebrospinal fluid and brain tissue. These findings are critical for early intervention and management (Hersh & Williams, 2018).

Holoprosencephaly is another significant condition that cranial ultrasound can reveal. It results from the failure of the forebrain to split into two distinct hemispheres. Ultrasound features of holoprosencephaly include a single, large ventricle and reduced cortical mantle. The severity of the condition can range from partial to complete fusion of the cerebral hemispheres, and accurate detection is essential for prognosis and management (Keppler-Noreuil et al., 2019).

Dandy-Walker malformation is a congenital brain defect involving cystic enlargement of the fourth ventricle and agenesis or hypoplasia of the cerebellar vermis. On cranial ultrasound, this appears as an enlarged fourth ventricle with the absence of normal cerebellar structures. Accurate diagnosis through ultrasound is vital for understanding the impact on motor and cognitive development (Sarnat & Flores-Sarnat, 2018).

Agenesis of the corpus callosum is a condition where the corpus callosum, the major neural structure connecting the brain's hemispheres, is absent or malformed. Ultrasound features include enlarged lateral ventricles and an abnormal interhemispheric fissure. This condition can significantly affect developmental outcomes, and early detection through cranial ultrasound is crucial for management (Schellinger et al., 2018).

Cystic brain lesions, such as subependymal, choroid plexus and arachnoid cysts, are also detectable via cranial ultrasound. These lesions are fluid-filled sacs located within the brain and vary in size and location. Monitoring the growth and impact of these cysts on surrounding brain structures is essential for determining the need for intervention and understanding potential effects on neurological function (Gupta & Khandelwal, 2020).

Subependymal cysts are most commonly observed in preterm infants, which is likely linked to the persistent presence of the germinal matrix at the caudothalamic groove. This area is particularly vulnerable, leading to a higher likelihood of hemorrhage. In many cases, congenital cysts are discovered incidentally in otherwise healthy newborns and may appear as isolated findings during routine examinations. Their presence, while often benign, can raise questions about underlying conditions.

These cysts also have notable associations with various factors, including congenital viral infections, especially cytomegalovirus and rubella. Additionally, they are linked to metabolic disorders such as Zellweger syndrome, chromosomal abnormalities, and even maternal cocaine use during pregnancy. Unlike true cysts, subependymal cysts are not lined with epithelium; instead, they are bordered by germinal cells and glial tissue. The presence of macrophage-like cells in the surrounding fluid suggests a vascular origin, highlighting the complex nature of these cysts (Chuang et al., 2007).

Subependymal cysts are usually positioned below the external angle of the lateral ventricles. This location is specifically posterior to the foramen of Monro and adjacent to the superior and lateral boundaries of the frontal horn. These cysts can vary in appearance and are most commonly detected via cranial ultrasound. However, interpreting the specific ultrasound images can pose a challenge, as it may be difficult to differentiate between post-hemorrhagic cysts, which develop following a bleed, and germinolytic cysts, which are congenital in nature. This distinction is important for accurate diagnosis and subsequent management. As noted by Chuang et al. (2007), the overlapping characteristics of these cysts can complicate clinical assessments and require careful evaluation by medical professionals.

Choroid plexus cysts are typically benign and often transient formations that arise in utero due to an in-folding of the neuroepithelium. These cysts do not possess an epithelial lining, which differentiates them from true cysts; instead, they are fluid-filled spaces located within the choroid plexus, containing clear cerebrospinal fluid (CSF) along with cellular debris. Their size can vary significantly, ranging from just a few millimeters to 1-2 cm. These cysts are most commonly observed at the atrial level of the lateral ventricles, particularly involving the choroid glomus. While they are usually detected during obstetric ultrasounds, they may persist into neonatal life and, less frequently, into adulthood. In cases where the cysts are particularly large, they can lead to obstructive (non-communicating) hydrocephalus, as noted by Behnke et al. (1999).

2.7 Cranial Ultrasonography protocol

2.7.1 Timing of the Cranial Ultrasound

Preterm babies are prone to vascular injuries, more commonly Germinal Matrix (GM) hemorrhage as well as Intraventricular Hemorrhage IVH. Vascular disruption may also lead to ischemic white matter injuries. This is more commonly occurring for babies less

than 32 weeks gestational age. The maximum risk of hemorrhage has been noted in preterm babies who were born before week 30. The incidence goes down to below 5% after 30 weeks. However, occasional scan anomalies have been unearthed after 30 weeks gestation therefore, for babies born 32 weeks and below it may be prudent to do routine cranial ultrasonography to rule out any pathologies early enough. (Sauve, 2001)

For babies less than 29 weeks an initial scan should be done around day 4-7 with a second scan between days 10-14. A Follow up scan can be done on a weekly basis if there is a pathology, otherwise, the next scan should be between 36–40 weeks of postpartum age

For babies between 30-32 weeks an initial scan should be done around day 3–7. Follow up scans should be done on a weekly basis if there is a pathology. Otherwise scan at term, or upon discharge whichever is earlier. Babies older than 32 weeks should have a scan only if clinically indicated. (Moraa E. O. et al)

2.7.2 Indications for Cranial Ultrasonography

The American Institute of Ultrasound in Medicine (AIUM) gives the following as indications for Cranial Ultrasound in babies:

- Brain infection.
- Head trauma.
- Rapid increase in head circumference.
- Ventriculomegaly.
- Suspected hemorrhage or brain parenchymal abnormalities
- Babies with congenital malformations.
- Vascular injuries and other abnormalities.
- Suspected hypoxic ischemic brain injury.

- Suspected central nervous system (CNS) pathology (e.g., neurological deficits, seizures).
- Craniosynostosis.
- Follow-up for babies with previously documented abnormalities
- Pre-surgical planning.

A brief discussion into areas not discussed in the rest of this document will include a few special areas. The first is convulsions. Seizures in neonates are another indication for cranial ultrasound. A study by Burchfield et al. (2018) emphasizes that cranial ultrasound can help identify potential structural causes of seizures, such as cortical malformations or hemorrhages. Quick identification of these issues is critical in guiding appropriate treatment and improving prognosis.

Additionally, cranial ultrasound can be used to monitor the progression of various neurological conditions. For instance, in infants diagnosed with hydrocephalus, regular cranial ultrasound examinations are essential for assessing ventricular size and the effectiveness of interventions such as shunt placement (Kumar et al., 2015). This monitoring is vital to prevent complications associated with untreated hydrocephalus, such as developmental delays or cognitive impairments.

In cases of traumatic brain injury, cranial ultrasound can also play a crucial role. Leclerc et al. (2021) documented that cranial ultrasound is effective in detecting brain injuries in infants following trauma, allowing for timely diagnosis and management. This is particularly important since infants may not exhibit obvious symptoms, making imaging a critical component of care.

Cranial ultrasound is also indicated for assessing conditions related to maternal infections, such as cytomegalovirus (CMV). A study by Kenneson and Cannon (2007)

suggests that cranial ultrasound can reveal signs of CMV infection in neonates, such as calcifications and ventriculomegaly. Early identification of these findings can inform management strategies and improve outcomes for affected infants.

Finally, cranial ultrasound can be utilized as part of a broader assessment for infants with unexplained developmental delays. According to a study by Shapiro et al. (2015), cranial ultrasound can uncover underlying structural abnormalities that may not be apparent through clinical evaluation alone. This can guide further diagnostic workup and therapeutic interventions tailored to the infant's needs.

2.8 Conceptual Framework

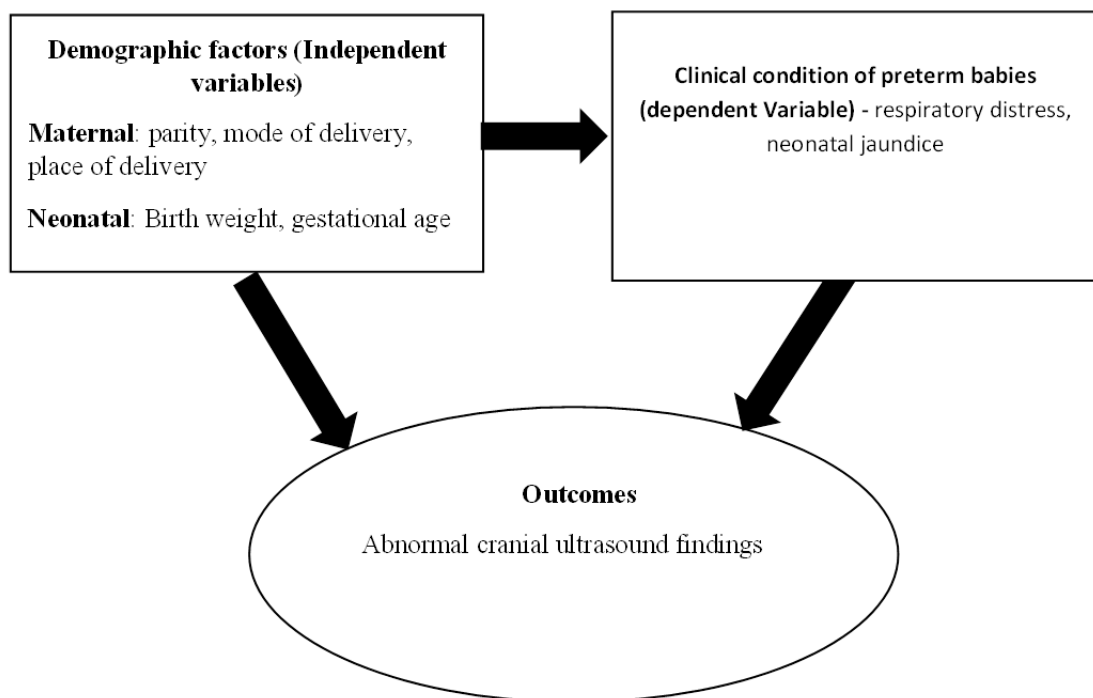


Figure 1: Conceptual Framework

CHAPTER THREE: METHODS

3.1 Overview

This chapter contains the various aspects of how the study was done including design, area, target population, inclusion criteria, exclusion criteria, sampling, data collection tool, data collection procedure, data management and ethical considerations.

3.2 Research Design

A cross-sectional study design was applied. Data was collected from all the respondents at a given point in time.

3.3 Study Area and Background of the Study Area

3.3.1 Study Area

This study was done at the Newborn Unit of Moi Teaching and Referral Hospital.

3.3.2. Background of Study Area

MTRH is recognized as one of the largest national hospitals in the country, alongside notable institutions such as Kenyatta National Hospital and Kenyatta University Teaching Referral and Research Hospital. It is strategically located in the town of Eldoret, within Uasin Gishu County. The hospital boasts a substantial bed capacity of approximately 1,020, enabling it to accommodate a wide range of patients. MTRH serves not only a clinical purpose but also plays a vital role in training and research through its collaboration with Moi University College of Health Sciences and various international universities. As a key referral hospital, it primarily caters to the western regions of Kenya, as well as patients from neighboring countries, including Tanzania, Uganda, South Sudan, and the Democratic Republic of Congo. This institution provides essential healthcare services to an estimated population of around 25 million people, significantly impacting the health outcomes in the region.

The Newborn Unit at MTRH is located within the Riley Mother and Baby Hospital, which has been operational for around 15 years and includes both maternal and neonatal services. It is considered one of the most advanced newborn units in western Kenya, serving both the private and public sectors. The unit is staffed by a team of highly skilled specialists, including obstetricians, neonatologists, pediatricians, pediatric residents, medical officers, medical interns, specialized nurses, and general nurses, among other professionals. Monthly admissions typically range from 250 to 300 infants. The unit has a capacity of 60 beds, including an 8-bed Neonatal Intensive Care Unit (NICU), 17 functional incubators, and several baby cots to provide essential neonatal care. It maintains a staffing ratio of approximately 1 nurse for every 15 neonates.

The newborn unit at MTRH, in conjunction with the well-equipped diagnostics laboratory, is capable of performing a wide variety of laboratory investigations. These assessments include hematological tests such as complete blood counts and peripheral blood films, which are essential for evaluating the overall health of the infants. Additionally, the unit conducts various serum biochemistry tests, including renal function tests, random blood sugar measurements, calcium level assessments, blood gas analysis, serum electrolytes, and liver function tests. Furthermore, it offers immunohistochemistry-based tests, such as procalcitonin and C-reactive protein levels, as well as microbiological tests, including cerebrospinal fluid (CSF) studies and blood cultures, to support accurate diagnosis and treatment.

Current pediatric protocols are regularly reviewed and adapted from WHO guidelines to ensure they remain effective and relevant. These protocols are customized to meet the specific needs of the newborn unit, taking into account both patient requirements and the availability of resources. This tailored approach enables the hospital to manage its patients efficiently and effectively, while also ensuring a high standard of care is

maintained at a comparatively low cost. By aligning with these guidelines, the unit can provide optimal care for newborns, ultimately improving health outcomes.

All infants who arrive at the facility and need admission are placed in the Newborn Unit (NBU). These babies may either be born at the hospital itself or be referred to the unit from other hospitals within the MTRH catchment area.

3.4 Study population

Preterm babies admitted at the Newborn unit born less than 37 weeks gestational age identified within the study period (September 2023 and March 2024)

3.4.1 Inclusion Criteria:

- Preterm babies admitted at the Newborn unit born less than 37 weeks gestational age.
- Preterm babies admitted at the NBU whose mothers provide consent.

3.4.2 Exclusion criteria:

- Patients who have already had an initial Ultrasound scan done and documented by another party.
- Patients with severe conditions with instrumentation obscuring access to the scalp.
- Post-operative patients e.g., post Venticulo-peritoneal shunting.

Recruitment Schema

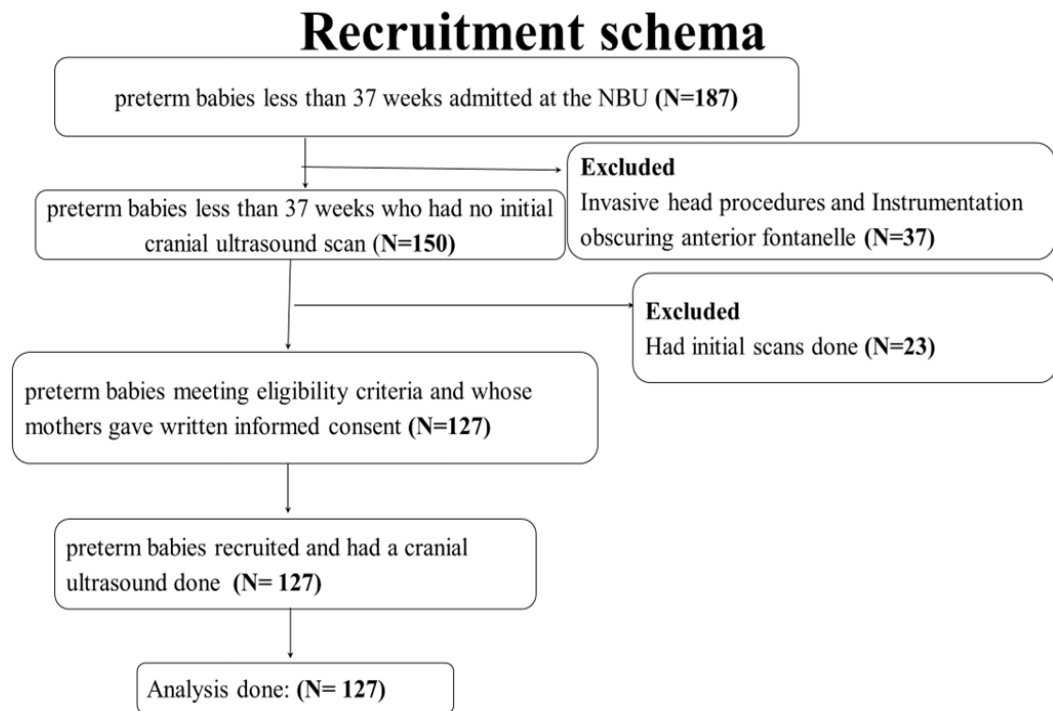


Figure 2: Recruitment Schema

3.5 Sampling and sample size

3.5.1 Sampling procedure

MTRH NBU was purposively sampled, having an Ultrasound diagnostic unit and a good record filing system for patient records.

Consecutive sampling of study participants was done from the time of approval until the required sample size was met.

3.5.2 Sample size

The sample size as calculated from Fisher's formula (Pourhoseingholi et al., 2013) with an assumption of 95% confidence level, 5% precision for effect size, and a reference for the prevalence of intracranial hemorrhage among preterm neonates at 33.8%. This is based on a study done in MTRH, "*Prevalence of intraventricular hemorrhage and*

determinants of its early outcomes among 2 preterm neonates at the newborn unit of a teaching hospital in Western Kenya”, that found that found 33.8% (68 preterm babies) of the 201 preterm babies less than 1.5kg birth weight had Intracranial Hemorrhage (Sisenda et al., 2022).

$$n = \frac{Z^2 P(1 - p)}{d^2}$$

Where;

n = Sample Size

Z = Level of Confidence (95%)

P = Prevalence (Sisenda et al., 2022)

d = precision effect size

$$n = \frac{1.96^2 \times 0.338 (1 - 0.338)}{0.05^2}$$

$$n = \frac{3.8416 \times 0.338 (0.662)}{0.0025}$$

$$n = \frac{1.2985 \times 0.662}{0.0025}$$

$$n = \frac{0.85958}{0.0025}$$

$$n = 343.83 \quad (\text{Rounded off to 344 babies.})$$

Adjustment for finite population using Cochran's formula (Bartlett et al., 2001)

$$nf = \frac{n}{1 + \frac{n}{N}}$$

nf = sample size after adjustment of finite population

n = sample size of 344 obtained from Fisher's formula (Pourhoseingholi et al., 2013)

as outlined above

N = population size (This was 201 pegged on the population sampled in the referenced study by Sisenda et. al)

$$nf = \frac{344}{1 + \frac{344}{201}}$$

= 126.8698 (Rounded off to 127 babies.)

3.6 Data Collection

3.6.1 Tools

A questionnaire was administered to mothers to obtain additional medical history and socio-demographic data.

Before administration, the questionnaire was pretested at a nearby hospital with 13 respondents (10% of the sample size). This allowed some improvements to be made to it. The hospital was comparable to MTRH citing it being a referral site sharing the same catchment and having a Neonatal unit albeit smaller in capacity.

The principal investigator and research assistant were responsible for the daily role of identifying and classifying new admissions according to the study's eligibility criteria. When the principal investigator was away, for example at night, the research assistant would identify and flag the babies for an ultrasound the next day, but not later than the first 3 days of life. For preterm babies fitting the study's inclusion criteria, the researchers explained the particulars of the study to their mothers. They proceeded to administer consent for those of legal age, and assent for mothers who were below 18 years, before recruiting the preterm baby into the study. The gestational age of the preterm baby was ascertained through confirmation of the last menstrual period in cases where mothers were sure of dates, and through 1st trimester ultrasound dates for the mothers who had one. In cases where neither was available, a ballard's score was done

to determine the babies' gestational age. The researcher then collected demographic and clinical traits of the mothers and neonates from the participants' files.

Patient files were reviewed to obtain further history, diagnosis as well as other significant clinical information. The information obtained was captured in the questionnaire.

3.6.2 The interviewer administered questionnaire.

During the study, social demographic data was collected using this questionnaire, included age, sex, and residence. Infant and maternal characteristics were collected as well. A respondent, in this case a mother, was included if they had a preterm baby aged 37 weeks and below and was due for a routine Cranial Ultrasound scan.

Clinical data was also collected that included but was not limited to, clinical diagnoses, symptoms and duration if any, relevant clinical history, and date of the first admission.

3.6.3 Patient files

Patient files were used to get collaborative history of the patients especially the clinical characteristics which the patients' diagnosis and clinical presentation. The information from the files was complimented by the mother-baby booklet, especially in cases where some information was missed during transcription to the patient file upon admission. There was no need to retrieve archived files whatsoever.

3.7 Study procedure

A two-stage study procedure was applied, that included planning and then followed by execution. The planning stage included recruitment of a research assistant and sensitization on the study as well as the deliverables. For this role a junior medical doctor was recruited. The research assistant was trained to understand the study objectives. The research assistant was also coached to understand the study's materials,

equipment and procedures. This was a 1-week training on the use of the study's primary screening tool, a Sonoscanner Orcheolite ultrasound machine, with 4 dimensional capabilities. There was a demonstration of the sites of storage within the ultrasound machine and how to extract and store the images. The staff at NBU were also sensitized about the study. The coverage included their understanding of the study, as well as the support in identifying any premature baby who could be included.

In the execution stage, the principal investigator (PI) identified mothers to preterm babies who had not had any Cranial Ultrasound scan and informed them about the study. Mothers who provided consent to have their babies included in the study, were subjected to a questionnaire that was administered to collect data touching on the social demographic details. Additionally, it was used to record collected additional maternal and neonatal information, clinical condition of the infant as well as record the eventual ultrasonographic findings. Participants were enumerated using Unique identifiers to maintain anonymity.

The PI using a Sonoscanner Orcheolite ultrasound machine, with 4 dimensional capabilities and convenient pediatric sized probes, used a high frequency sector transducer of frequencies ranging between 5 – 7.5 MHZ with a curvilinear probe to obtain the initial Ultrasonographic findings for preterm babies who had no prior scan done.

Data was collected every day as cases arose during the study period. Newly admitted preterm babies (3 days or less) were identified from the admission book at the NBU. Assumption made at this point, was that the age of the infant provided by the pediatric team was as accurate as possible after confirmation of maternal last menstrual dates, previous ultrasonographic first trimester delivery dates estimations, or a clinical evaluation from a Ballard score for the mothers who had neither. The scans included

were initial (routine) ones taken from day 3 and not later than day 7 after birth. Subsequent scans and post intervention scans were not included. The images were reviewed by the PI as well as the patient files and Ultrasound reports. Images were stored securely for review and documentation. Findings in the images were verified by the consultant radiologist to ascertain validity and reliability. This was done before documentation. In cases on contention, a second consultant's opinion was sought.

The research assistant assisted with data cleaning, collation and compilation of data in readiness for analysis closely guided by the P.I.

3.8 Data collection, storage, analysis, and presentation

Data collection:

A comprehensive questionnaire, featuring unique de-identified serial numbers for each respondent, was administered to gather additional medical history and socio-demographic data. This structured approach facilitated the collection of relevant information while ensuring the anonymity of participants. In addition to the responses provided by the participants, data from patient records were also meticulously documented within the questionnaire to provide a more complete picture of each individual's medical background. Prior to its full deployment, this questionnaire underwent a pre-testing phase in a pilot study. Based on the feedback and results from this pilot, necessary adjustments were made to enhance and improve the questionnaire's clarity and effectiveness.

Data Storage and safety

The completed questionnaires were securely stored in a designated location that was locked and accessible only to the Principal Investigator (P.I.). This ensures the confidentiality and integrity of the data collected. In addition to the questionnaires, the

data gathered included de-identified images and various other types of soft data. This sensitive information was stored in a password-protected database, further safeguarding it from unauthorized access. Access to this database was also restricted solely to the P.I., ensuring that all collected data remained confidential and was handled in compliance with ethical standards and privacy regulations throughout the study.

Independent Variables:

Patient demographics (gestational age, gender, birth weight). This included maternal factors too such as parity.

Outcome Variables:

Patterns of Cranial Ultrasonographic findings.

Data analysis:

STATA version 16 was used for analysis. The analysis employed descriptive statistics, specifically frequencies and proportions, to summarize categorical variables. These included sociodemographic data for both mothers and their preterm infants, such as the place and mode of delivery, as well as the gender of the preterm babies. This information was effectively organized and presented in tables, facilitating easy interpretation.

For continuous variables, which illustrated patterns observed in the ultrasound scans and the clinical conditions of the preterm infants, means and standard deviations (SD) were calculated. This approach allowed for a comprehensive understanding of the data distribution and variability among the clinical measurements.

Bivariate analysis was performed using the Pearson Chi-Square test and Fisher's exact test to assess the relationship between abnormal cranial ultrasound findings and categorical variables within the study, such as maternal parity, gestational age, and birth

weight. A significance level was established with p-values of less than 0.05, indicating statistical significance. This careful consideration of statistical methods ensures that the relationships observed are meaningful and not due to random chance.

Multivariate analysis was conducted to delve deeper into the relationship between abnormal cranial ultrasound findings and the categorical variables, utilizing the Adjusted Odds Ratio (AOR). This approach allowed for the control of potential confounding factors, enhancing the reliability of the findings. The results from both the bivariate and multivariate analyses were comprehensively displayed in tables, providing clear visual representations of the data and facilitating the interpretation of complex relationships among the variables studied.

3.9 Ethical considerations

Approval to carry out the study was sought from the Moi Teaching and Referral Hospital & Moi University's Institutional Research and Ethics Committee (IREC). At several stages the document was reviewed by a team and feedback sent back for amendments. Several other documents disclosing the scope of the research, the participants, and other considerations were completed and approved. All this was done prior to approval and commencement of the study to ensure safety of the participants as well as ensure the quality of the research.

Approval was also obtained from NACOSTI (National Commission for Science, Technology and Innovation) before commencement of the study. This is the body mandated to regulate and assure quality in the research, science, and technology and innovation sector and advise the Government in matters related thereto. This commission Regulates, Coordinates, Advises and promotes Science, Technology, Innovation and Research activities within the country.

Permission and approval were also sought from the chief executive officer of MTRH. Written informed consent was sought from the mothers of all eligible participants.

All babies included in the study received standard care according to their diagnosis. The study did not provide any separate package offering any more or less of what the babies should have received as care. There was no additional cost outside the accessible standard of care.

Confidentiality was maintained throughout the whole cascade through de-identification of subjects and secure storage of the data. Adequate data protection protocols were applied including the use of passwords for its digital data. Secure and lockable document cabinets were used for physical records. At all points no patient data was shared or exposed knowingly or unknowingly. This was ensured by the deidentification of all collected records and data.

CHAPTER FOUR: FINDINGS

4.1 OVERVIEW

The study findings are based on 127 preterm babies admitted at the Newborn unit born less than 37 weeks gestational age identified within the study period (September 2023 and March 2024).

4.2 DEMOGRAPHIC AND CLINICAL CHARACTERISTICS

The female preterm babies were slightly more (54.3%) compared to males (45.7%).

The mean gestational age was 29.5 with a standard deviation of ± 3.1 . Most of the babies reside in Uasin Gishu county (51.2%)

Table 1: Demographic characteristics

	Total
	N=127
Gestational age (weeks)	
Mean (SD)	29.5 (3.1)
Range	20 - 37
Gender	
Male	58 (45.7%)
Female	69 (54.3%)
County of residence	
Uasin Gishu	65 (51.2%)
Nandi	18 (14.2%)
Bungoma	16 (12.6%)
Elgeyo Marakwet	14 (11.0%)
Kakamega	6 (4.7%)
Transnzoia	4 (3.1%)
Baringo	2 (1.6%)
Kericho	2 (1.6%)

According to this data, 41.7% of the mothers whose babies were included in the study had a parity of 2 with 21.3% having a previous viable pregnancy loss. 96.1% of the mothers delivered in hospital, 60.6% through SVD (Spontaneous Vaginal Delivery). The majority of the babies (55.1%) were Very Preterm. The largest proportion of the babies (46.5%) weighed between 1000-1500 grams.

Table 2: Neonatal and maternal characteristics

	Total
	N=127
Maternal characteristics	
Mothers' parity	
1	24 (18.9%)
2	53 (41.7%)
3	30 (23.6%)
4	17 (13.4%)
5	3 (2.4%)
Previous viable pregnancy loss	
No	100 (78.7%)
Yes	27 (21.3%)
Neonatal Characteristics	
Place of birth	
Hospital	122 (96.1%)
Home	5 (3.9%)
Gestational age at birth	
Mod to late Preterm (33-37)	25 (19.7%)
Very preterm (<32 wks.)	70 (55.1%)
Extremely pre-term (<28 wks.)	32 (25.2%)
Mode of delivery	
SVD	77 (60.6%)
CS	50 (39.4%)
Birth weight category	
>2500	6 (4.7%)
1500-2500	42 (33.1%)
1000-1500	59 (46.5%)
750-1000	18 (14.2%)
<750	2 (1.6%)

4.3 ROUTINE CRANIAL ULTRASONOGRAPHIC PATTERNS

63.8% of the preterm babies had a normal cranial ultrasound. The remainder (36.2%) had abnormal findings which included Hemorrhage (23.6%), Ventriculomegaly (18.9%), Periventricular Leukomalacia and Congenital anomalies each at (3.2%). Congenital anomalies included Neural Tube defects, Choroid Plexus Cysts, and sub-ependymal cysts.

Amongst the 30 babies who had hemorrhage, 12 (40%) had grade II IVH, 10 (33.3%) had grade I IVH and 2 (6.7%) had grade IV IVH. This accounts for 9.4 %, 7.9% and 1.6% respectively overall. 6 (20%) preterm babies had intracerebral bleeds accounting for 4.7% of all the 127 babies.

For the 24 preterm babies with Ventriculomegaly, 16 (66.7%) had communicating type versus 8 (33.3%) who had the non-communicating type.

3.2% of the premature babies had Periventricular leukomalacia. According to severity of disease 1.6% had grade 1 PVL and 1.6% had grade 3 PVL. Only 3.2% of the premature babies had congenital anomalies, 1.6% with neural tube defects, 0.8% with a choroid plexus cyst and 0.8% with sub-ependymal cysts.

Table 3: Routine Cranial Ultrasonographic patterns

	Total N=127
Normal scan	
Normal	81 (63.8%)
Abnormal	46 (36.2%)
Hemorrhage	30 (23.6%)
Ventriculomegaly	24 (18.9%)
Periventricular Leukomalacia	4 (9.1%)
Congenital anomalies	4 (9.1%)
Hemorrhage grade	
Grade 1	10 (33.3%)
Grade 2	12 (40.0%)
Grade 4	2 (6.7%)
Intraparenchymal	6 (20.0%)
Ventriculomegaly categories	
Non communicating ventriculomegaly	8 (33.3%)
Communicating Ventriculomegaly	16 (66.7%)
Periventricular Leukomalacia	
Grade 1	2 (50.0%)
Grade 3	2 (50.0%)
Congenital anomalies	
Neural Tube Defects	2 (50.0%)
Choroid plexus cysts	1 (25.0%)
Subependymal cysts	1 (25.0%)

NB: an infant could have more than one condition at the same time

Table 4: Summary of ventricular assessment for the infants with Ventriculomegaly

Gestational Age (weeks) (25-34)	Evans Index (normal < 0.3)	Thalamo-Occipital Distance (mm) (normal 8.7–24.7)	Anterior Horn Width (mm) (normal 0–2.9)
28	0.30	40	8
30	0.32	42	7.5
26	0.35	38	9
29	0.33	36	8.5
31	0.31	41	7.8
27	0.34	39	8.2
25	0.36	37	8.7
32	0.29	43	7.4
28	0.32	40	8.0
30	0.30	36	8.3
29	0.31	42	7.9
26	0.37	38	9.2
31	0.33	41	7.6
28	0.30	39	8.1
25	0.35	43	8.5
27	0.34	40	7.8
29	0.36	37	9.0
30	0.33	36	8.4
31	0.30	42	7.7
28	0.31	40	8.6
27	0.32	41	7.5
29	0.34	39	8.0
25	0.35	43	8.2
30	0.36	38	7.9

The dataset includes measurements from 24 preterm infants with ventriculomegaly and gestational ages range from 25 to 34 weeks, focusing on three key parameters for objective assessment: Evans Index, Thalamo-Occipital Distance and Anterior Horn width. Evans Index values predominantly exceed the normal range of less than 0.3, with some as high as 0.37. Similarly, Thalamo-Occipital Distance values exceed the normal range of 8.7–24.7 mm, reaching above 40 mm in several cases. Anterior Horn Width measurements are all outside the normal range of 0–2.9 mm, with values up to 9.2 mm.

Table 5: MCA doppler findings for infants with Intracranial hemorrhage

Infant	Grade of IVH	Gestational Age (weeks)	Peak Systolic Volume (cm/s)	Pulsatility Index	Resistive Index
1	Grade 1	28	45	1.5	0.7
2	Grade 1	29	42	1.4	0.68
3	Grade 1	30	50	1.6	0.72
4	Grade 1	31	40	1.3	0.65
5	Grade 1	32	48	1.5	0.70
6	Grade 2	28	65	1.8	0.74
7	Grade 2	29	60	1.7	0.73
8	Grade 2	30	70	1.9	0.76
9	Grade 2	31	68	1.85	0.75
10	Grade 2	32	73	1.8	0.77
11	Grade 2	29	66	1.6	0.71
12	Grade 2	30	69	1.9	0.78
13	Grade 4	28	95	2.5	0.82
14	Grade 4	29	92	2.4	0.81
15	Intraparenchymal	27	75	1.6	0.74
16	Intraparenchymal	28	80	1.7	0.77
17	Intraparenchymal	29	78	1.65	0.75
18	Intraparenchymal	30	82	1.8	0.79
19	Intraparenchymal	31	76	1.55	0.72
20	Intraparenchymal	32	84	1.9	0.78
21	Grade 1	30	47	1.5	0.69
22	Grade 1	29	44	1.4	0.66
23	Grade 1	28	49	1.6	0.71
24	Grade 2	31	64	1.8	0.74
25	Grade 2	32	70	1.9	0.76
26	Grade 2	30	67	1.85	0.72
27	Grade 2	28	62	1.7	0.73
28	Grade 4	29	90	2.3	0.80
29	Grade 4	31	93	2.4	0.81
30	Grade 4	30	88	2.2	0.79

Infants with Grade 1 IVH exhibit peak systolic volume (PSV) values ranging from 40 to 50 cm/s, with pulsatility index (PI) values between 1.3 and 1.6. Those with Grade 2 IVH show higher PSV ranges of 60 to 73 cm/s and PI values from 1.6 to 1.9. Infants with Grade 4 IVH present significantly elevated PSV values between 92 and 95 cm/s and PI values reaching up to 2.5. Intraparenchymal hemorrhage cases present PSV values ranging from 75 to 84 cm/s and PI values of 1.55 to 1.9.

4.4 DEMOGRAPHIC FACTORS ASSOCIATED WITH THE ULTRASONOGRAPHIC FINDINGS

There was a significant association between gestational age and abnormal Ultrasonographic findings with a P-value of 0.002 with the highest proportion accounted for by the extremely pre-term (62.5%). Birth weight also had a significant association with a P-value of <0.001 with the babies weighing less than 1000 grams taking the highest proportion (70.0%). Mother's parity also had significant association with a P-value of 0.024. Those who had 4 or more children accounted for 83.5% of the babies who had abnormal findings. The other demographic factors, gender, previous viable pregnancy loss, place of birth and mode of delivery showed no significant association.

Table 6: Demographic factors associated with abnormal ultrasonographic findings

	Normal N=81	Abnormal N=46	p-value
Gender			0.267 ^c
Male	34 (58.6%)	24 (41.4%)	
Female	47 (68.1%)	22 (31.9%)	
Mothers' parity			0.024 ^f
1	18 (75.0%)	6 (25.0%)	
2	35 (66.0%)	18 (34.0%)	
3	12 (40.0%)	18 (60.0%)	
4+	16 (80.0%)	4 (20.0%)	
Previous pregnancy loss			0.057 ^c
No	68 (68.0%)	32 (32.0%)	
Yes	13 (48.1%)	14 (51.9%)	
Place of birth			0.158 ^f
Hospital	76 (62.3%)	46 (37.7%)	
Home	5 (100.0%)	0 (0.0%)	
Gestational age at birth			0.002 ^c
Mod to late Preterm (33-37)	19 (76.0%)	6 (24.0%)	
Very preterm (<32 wks.)	50 (71.4%)	20 (28.6%)	
Extremely pre-term (<28 wks.)	12 (37.5%)	20 (62.5%)	
Mode of delivery			0.967 ^c
SVD	49 (63.6%)	28 (36.4%)	
CS	32 (64.0%)	18 (36.0%)	
Birth weight category			<0.001 ^f
>2500	4 (66.7%)	2 (33.3%)	
1500-2500	36 (85.7%)	6 (14.3%)	
1000-1500	35 (59.3%)	24 (40.7%)	
<1000	6 (30.0%)	14 (70.0%)	

^c Chi Square test

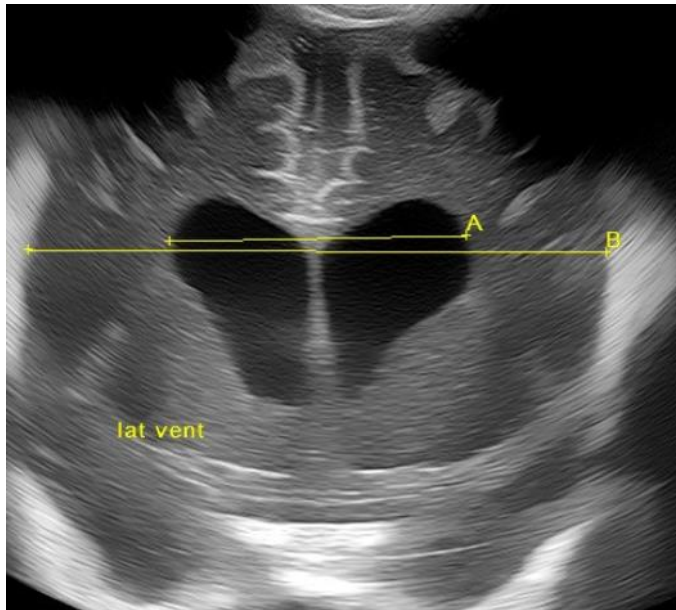
^f Fisher's Exact test

The Odds for a mother with 3 children to have an abnormal ultrasounds scan result were 3.4 times with reference to a primiparous woman with a 95% Confidence interval of 0.697 – 16.475. The odds for an extremely preterm infant (< 28 weeks) having an abnormal scan were 0.9 times more likely with a 95% confidence interval of 0.160 – 5.147. The preterm babies who weighed 1000 grams or less had an Adjusted odd's ratio of 7.3 times as compared to those weighing above 2500 grams with a 95% confidence interval of 0.523 - 102.467. However, in the multi-variate regression, none of the demographic factors are independent predictors having P-values that are statistically insignificant.

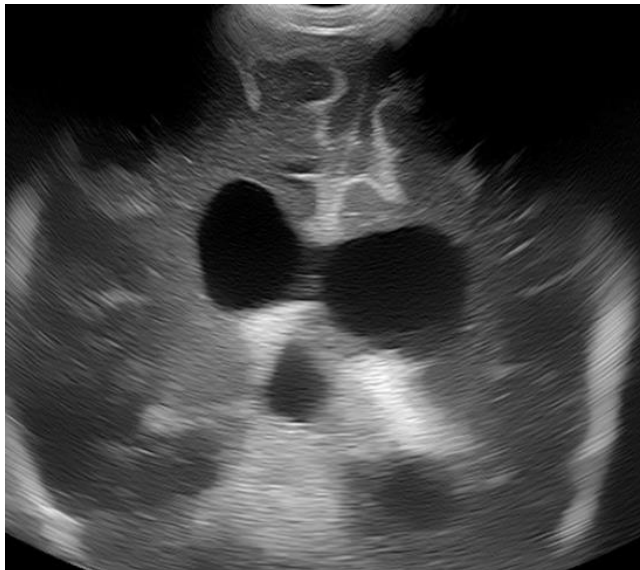
Table 7: Demographic factors associated with abnormal ultrasonographic findings multivariate analysis

Factor	aOR	p-value	95% CI
Mothers' parity			
1	Ref		
2	0.882	0.859	0.221 – 3.514
3	3.390	0.130	0.697 – 16.475
≥4	0.576	0.546	0.096 – 3.386
Gestational age at birth			
Mod to late Preterm (33-37)	Ref		
Very preterm (<32 wks.)	0.489	0.360	0.106 – 2.260
Extremely pre-term (<28 wks.)	0.908	0.913	0.160 – 5.147
Birth weight			
>2500	Ref		
1500-2500	0.437	0.476	0.045 – 4.254
1000-1500	1.435	0.779	0.115 - 17.948
<1000	7.323	0.139	0.523 - 102.467

aOR – Adjusted Odd's Ratio

SAMPLE IMAGES**Figure 3: Ventriculomegaly assessment**

Coronal cranial ultrasound image of preterm infant with ventriculomegaly and effacement of sulci and gyri with an Evans Index of 44/86 0. 51 (normal range = 0.25 - 0.30)

**Figure 4: Ventriculomegaly assessment coronal views**

Same infant with coronal views through the 3rd ventricle indicating its enlargement

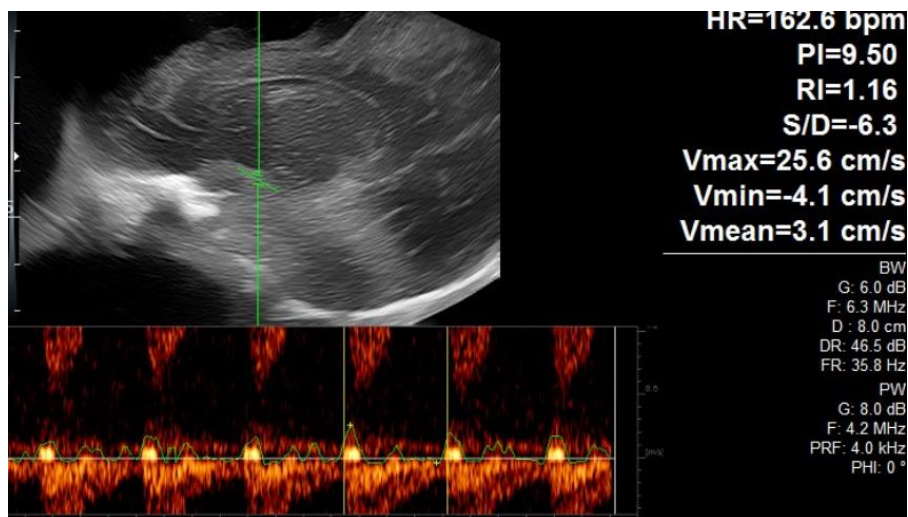


Figure 5: Doppler waveforms

A Middle Cerebral Artery Doppler of a preterm infant with Intraventricular Hemorrhage grade 1, indicating Reversal of flow and high Resistive index (normal range 0.6-0.9 median of 0.72).

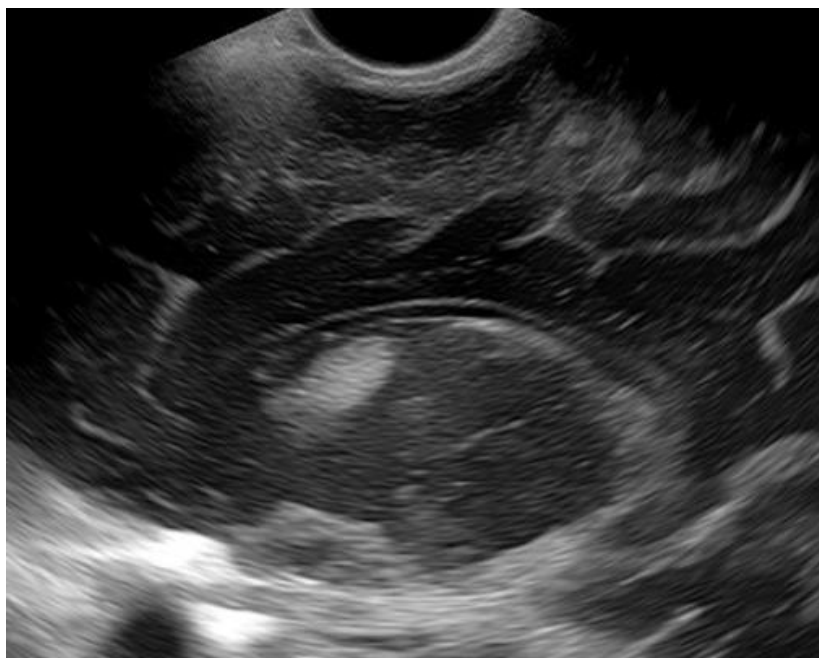


Figure 6: Grade 1 IVH sagittal

Sagittal scan angulated just lateral to the midline in the same infant above indicating a hyperechoic collection within the Germinal matrix just anterior to the caudothalamic groove indicative of grade I IVH.

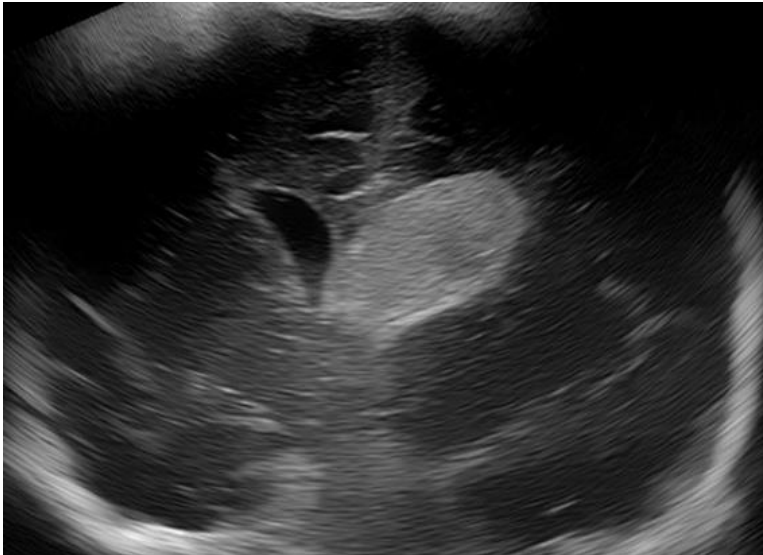


Figure 7: Grade 4 IVH coronal

Coronal image of a preterm infant showing left sided grade IV IVH with bilateral ventriculomegaly though predominantly left sided.

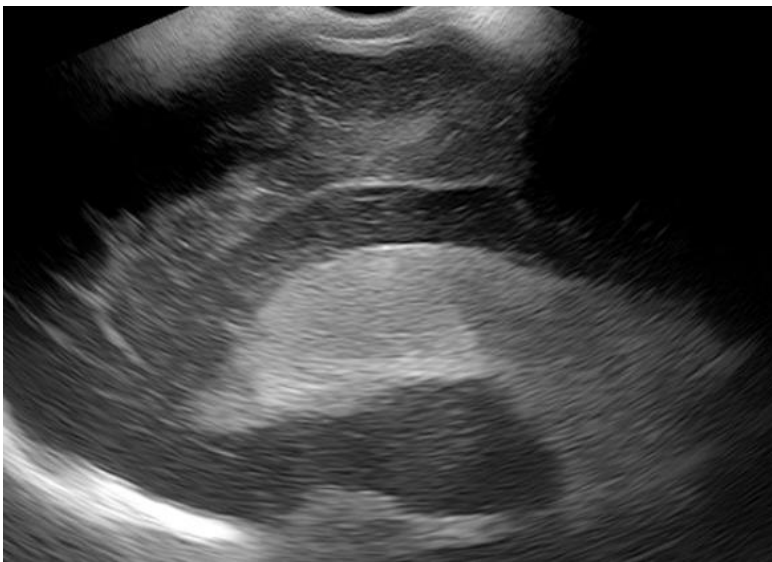


Figure 8: Grade 4 IVH sagittal

Sagittal image of the same infant above.

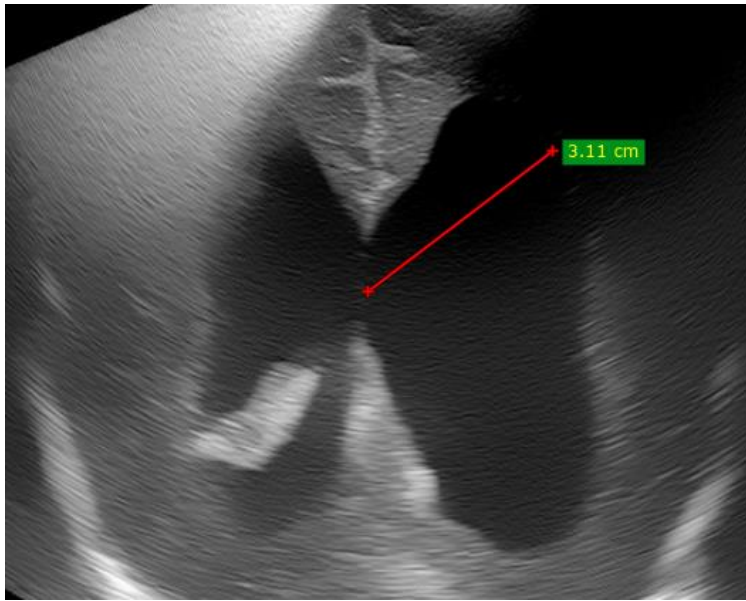


Figure 9: Ventriculomegaly with midline shift

A coronal image of a preterm infant with ventriculomegaly illustrating slight midline shift to the right, anterior horn width of taken diagonally at the widest dimension (normal range = 0 mm to 2.9 mm)

NB: these are sample images collected from the premature infants during the study.

CHAPTER FIVE: DISCUSSION

5.0 Overview

This chapter seeks to get a deep dive analysis of the results found in comparison to other similar studies.

5.1 Routine Cranial Ultrasonographic findings in preterm babies at the MTRH NBU.

Cranial ultrasound (CUS) is a non-invasive imaging technique extensively used in many Newborn Units, especially neonatal intensive care units (NICUs) to assess brain structures and detect abnormalities in preterm babies. Application of CUS in preterm babies seeks to ensure early detection and intervention for neurological issues, and when that can't be done, it allows counselling of the mother's early on the possible short-, medium- and long-term complications of the specific condition.

In this study, 81 preterm babies (63.8%) had a normal cranial ultrasound scan. This can be attributed to several factors related to current maternal, intrapartum, and neonatal care practices being implemented at MTRH. One crucial aspect is the quality of antenatal care received by the mothers at the Riley Mother and baby wing. Most of the preterm infants in this study, were born to mothers who had access to regular prenatal check-ups, appropriate management of underlying health conditions, and timely interventions during pregnancy. Other factors surrounding maternal health, including nutrition, prompt treatment of infections, and timely management of chronic illnesses, also possibly played a pivotal role in reducing the risks of complications, leading to healthier brain development.

Another contributing factor is the advancements in neonatal care and technology that have improved outcomes for preterm infants at the hospital. This together with skilled

healthcare professionals, at different levels may have provided timely interventions that prevented the onset of severe conditions. At both the Ante-natal and at the NBU at MTRH, implementation of protocols for the care of preterm infants have also improved outcomes. Early access to CPAP, including the use of maternal corticosteroids for lung maturation, proper thermal management, and careful monitoring during the neonatal period, implemented at MTRH positively influenced cranial ultrasound outcomes.

The developmental milestones and gestational age at the time of birth is a significant factor. Preterm infants delivered closer to term (around 32-33 weeks) have a lower likelihood of brain injuries compared to those born extremely preterm (below 28 weeks). This is primarily due to the increased maturity of the brain and vascular systems, which are less vulnerable to injuries like hemorrhage as gestation progresses. Additionally, factors such as optimal delivery conditions and immediate postnatal care can further enhance infant outcomes and contribute to a greater number of normal cranial ultrasound findings in this population.

Kamau et al. (2018), at the Kenyatta National Hospital found that the majority of preterm babies exhibited normal cranial ultrasound findings. This study involved 150 preterm babies, of whom 85% had normal ultrasound results. It differs with this study, despite both being cross sectional studies, and also having a similar setting; tertiary hospitals. The differences may be attributed to better number of equipment at KNH allowing easier access to timely intervention. A good example would be a higher CPAP to infant ratio at KNH as compared to our setup.

The study emphasized the importance of routine CUS in this population for early identification of those at risk of developing neurological complications.

Okechukwu et al. (2016), found that approximately 78% of the 200 preterm babies studied had normal cranial ultrasound results. This study highlighted the effectiveness of CUS as a screening tool in detecting early brain abnormalities and the high prevalence of normal findings, suggesting that most preterm babies may not have immediate neurological concerns.

Levene et al. (2014), followed 500 preterm babies and found that 78% had normal cranial ultrasound findings. The study provided insights into the long-term neurological outcomes of preterm babies with initially normal CUS results, demonstrating that most remained neurologically intact during follow-up.

This study found 46 (36.2%) preterm babies with abnormal cranial ultrasound findings. Out of the 46 babies, 30 (63.6%) had hemorrhage, accounting for 23.6% of all the babies in the study.

One major contributor is the vulnerability of preterm infants due to their underdeveloped neurological systems. In this study, majority of the infants were very preterm. Preterm infants, especially those born before 28 weeks of gestation, have delicate cerebral blood vessels in the germinal matrix that are more susceptible to rupture under stress during or after delivery. This fragility can lead to varying degrees of intracranial hemorrhage, which is often exacerbated by unstable hemodynamics, as they may experience fluctuations in blood pressure and poor perfusion shortly after birth.

A study conducted at the Kenyatta National Hospital indicated that approximately 18% of preterm babies developed IVH, with a significant number of cases occurring in babies born before 30 weeks of gestation (Mwaniki et al., 2012).

Another plausible factor is the intrapartum and delivery conditions surrounding these preterm infants. Factors such as the mode of delivery (e.g., emergency cesarean versus vaginal birth), the occurrence of birth asphyxia, and the use of instruments during delivery can increase the risk of brain injury in preterm infants. In this study, most of the infants were born through spontaneous vaginal delivery and had good Apgar scores. Maternal complications during labor, such as chorioamnionitis or preeclampsia, can negatively impact fetal well-being and increase the likelihood of adverse cranial findings. They also may lead to preterm delivery especially if severe. In this study, out of the 127 infants, 28 were born prematurely due to maternal chronic diseases that necessitated early delivery.

At MTRH in one of the first studies of its kind in Western Kenya, Sisenda et al. (2022), reported an IVH prevalence of 33.8% among the babies admitted at the NBU. This study was looking at the prevalence of IVH and trying to discern the maternal factors associated with it. It sampled 201 infants and enumerated maternal and perinatal factors that are predictors of IVH.

The postnatal environment and care provided immediately after birth significantly impact the risk of abnormal cranial findings. Factors such as the quality of neonatal intensive care unit (NICU) resources, staff experience, and adherence to clinical protocols for monitoring and managing preterm infants are critical. Poor management of respiratory distress or infections can further compromise the stability of preterm infants, creating a cascade of physiological challenges that predispose them to hemorrhage and other intracranial abnormalities. This combination of vulnerable fetal development, adverse birth circumstances, and suboptimal postnatal care likely contributes to the notable incidence of abnormal cranial ultrasound findings observed in the study.

Papile et al. (1978), established the grading system for IVH, which remains widely used today. This system classifies IVH into four grades based on the extent and location of the hemorrhage, with grades III and IV being associated with higher risks of long-term neurodevelopmental impairments. In this study, among the 30 preterm babies who had hemorrhage, 12 (40%) had grade II IVH, 10 (33.3%) had grade I IVH and 2 (6.7%) had grade IV IVH. This accounts for 9.4 %, 7.9% and 1.6% respectively overall. 6 (20%) preterm babies had intracerebral bleeds accounting for 4.7% of all the 127 babies.

In this study, grade II IVH was the most common. Grade II IVH was characterized by bleeding into the ventricular system but without significant ventricular enlargement. While it is considered moderate in severity, for these infants, it poses risk for developmental delays, neurological deficits, and long-term complications, thereby contributing to increased morbidity during the early neonatal period.

Following grade II IVH, grade I IVH was the next most common type of hemorrhage. This involved bleeding limited to the germinal matrix, the subependymal area around the caudothalamic groove. This region has immature and fragile blood vessels in the fetal brain, and typically had a good prognosis. Infants with grade I IVH usually do not often experience significant long-term neurodevelopmental disabilities. (Ment et. Al 1984) In this context, the presence of grade I and II IVH in a large proportion of infants could indicate the importance of careful monitoring and early interventions.

The more severe cases, represented by grade IV IVH in 2 infants (6.7%) and accounting for 1.6% of the overall population, indicated more serious brain injury, where bleeding extended into the brain parenchyma with the presence of ventriculomegaly. Grade IV IVH was associated with a higher risk of developing significant neurologic impairments and poor long-term outcomes, including a higher likelihood of cerebral palsy and cognitive deficits, further impacting morbidity and mortality rates in this group.

A study by Mwangi et al. (2018) examined the prevalence of IVH in preterm babies admitted to the Kenyatta National Hospital's newborn unit found that 30% of preterm babies had some form of IVH, with Grade I and II hemorrhages being the most common at 15% and 10% respectively, while Grade III and IV were less frequent at 3% and 2% respectively. This was a cross sectional study including 238 preterm babies and comparable to this study.

Intracerebral hemorrhage (ICH) is less common but more devastating with poorer clinical outcomes. In a study conducted in India, Chawla et al. (2015) found a 5% prevalence of ICH in preterm babies. A Canadian study by Schmidt et al. (2014) reported a lower prevalence of ICH at 3% among preterm babies. The study attributed this to the widespread use of advanced neuroimaging techniques and early therapeutic interventions. These findings highlight the disparity in neonatal care between developed and developing countries, impacting the prevalence and outcomes of ICH.

In this study, the presence of intracerebral bleeds in 6 infants accounting for 4.7% of the total studied cohort, suggested an elevated risk of more severe neurological consequences. Intracranial hemorrhage indicates direct injury to brain parenchyma, which could lead to increased mortality rates and poorer long-term outcomes. Four out of the 6 infants had perinatal asphyxia and needed assisted delivery.

One of the significant findings on CUS was ventriculomegaly, an enlargement of the brain ventricles. This condition is of particular concern in preterm babies due to their vulnerability to brain injuries and developmental complications. Ventriculomegaly can be an indicator of intraventricular hemorrhage (IVH), post-hemorrhagic hydrocephalus, or other underlying neurological conditions (Leijser et al., 2020).

This study found 24 (18.9%) preterm babies with Ventriculomegaly, of whom 16 (67.7%) had communicating type versus 8 (33.3%) who had the non-communicating type.

Ventriculomegaly, can result from various factors, particularly in preterm infants whose neurological systems are still developing. One plausible cause is the presence of intraventricular hemorrhage (IVH), which is common in preterm infants due to their fragile blood vessels. Hemorrhagic events can disrupt the normal cerebrospinal fluid (CSF) circulation and lead to ventricular enlargement. Additionally, infections, such as meningitis or chorioamnionitis, can also contribute to ventriculomegaly by causing inflammation and disrupting the normal flow and absorption of CSF.

Among the infants diagnosed with ventriculomegaly in this study majority had communicating ventriculomegaly. Communicating ventriculomegaly occurs when there is an extra-ventricular in the CSF pathways, disrupting free absorption of CSF in the arachnoid granulations leading to ventricular enlargement. This could occur due to prior hemorrhagic events.

In contrast, non-communicating ventriculomegaly, observed in 8 infants, suggests a blockage in the CSF pathways, which can be due to structural anomalies or masses within the brain. Understanding the type of ventriculomegaly is crucial for determining the potential interventions required and the prognosis for each infant.

IVH not only inflicts immediate harm to nearby structures due to mass effect and increased intracranial pressure, but the resulting inflammation also leads to further brain injury and swelling. Among neonates with severe IVH, 25-30% will develop post-hemorrhagic hydrocephalus (PHH). This condition increases the risk of white matter damage, seizures, and mortality in both neonates and adults. (Holste et. al., 2022)

The long-term consequences of ventriculomegaly in preterm infants can be significant and varied. Infants with communicating ventriculomegaly may experience fewer complications if the underlying causes, such as IVH, are managed effectively. However, they still face risks of developmental delays, cognitive impairments, and motor function issues as they grow. On the other hand, those with non-communicating ventriculomegaly might experience more severe outcomes due to the potential for increased intracranial pressure and associated brain injury.

Olufemi et al. (2016) reported a ventriculomegaly prevalence of 10%, lower than that reported in Kenyan studies. These variations may have been attributed to differences in neonatal care practices, availability of diagnostic tools, and genetic factors.

A study done in India found ventriculomegaly in 6.6% of the infants sampled. The study was a meta-analysis including preterm babies between 29 and 33 weeks, had a sample size 4184, and had a focus on preterm cranial ultrasound findings. Comparatively, the lower percentage would have been attributed to the larger sample size, as well as inclusion of more babies with low birth weight and higher rates of small for gestational age. (Natarajan et. al., 2018).

The Evans index (EI), and anterior horn width (AHW) and thalamo-occipital distance are critical neuroimaging parameters used to assess the size and shape of the brain's ventricles, which can be indicative of various neurological conditions. The ventricular index is measured as the width of the lateral ventricles divided by the width of the brain at the same level, providing an assessment of ventricular dilation (Lai et al., 2022).

In this study, Evans Index values predominantly exceed the normal range of less than 0.3, with some as high as 0.37. Similarly, Thalamo-Occipital Distance values exceed the normal range of 8.7–24.7 mm, reaching above 40 mm in several cases. These

findings indicate notable ventriculomegaly. Anterior Horn Width measurements are all outside the normal range of 0–2.9 mm, with values up to 9.2 mm. The infants' gestational ages range from 25 to 34 weeks, indicating significant prematurity.

The Evans index, named after the neurologist William Evans, is the ratio of the maximal frontal horn width of the lateral ventricles to the maximal internal diameter of the skull. An Evans index greater than 0.3 is suggestive of ventriculomegaly and is commonly used in the diagnosis of normal pressure hydrocephalus (NPH) (Kim et al., 2014). This index is advantageous due to its simplicity and reproducibility, making it a valuable tool in both clinical and research settings for the assessment of ventricular enlargement (Lai et al., 2022).

Anterior horn width is a measurement taken in the coronal plane taking the diagonal width of the anterior horn of the lateral ventricle at its widest point. Thalamo-occipital distance is the length taken in the parasagittal plane, between the most posterior surface of the thalamus at its junction with the choroid plexus and the outermost point of the occipital horn. (Brouwer et.al., 2012)

These indices—thalamo-occipital distance, Evans index, and anterior horn width—are essential tools in neuroimaging, offering critical insights into the structural changes of the brain's ventricles. They aid in the diagnosis and monitoring of various neurological conditions, including hydrocephalus and neurodegenerative diseases. Their application in clinical practice and research underscores the importance of accurate and reliable neuroimaging metrics in understanding and managing brain health (Kim et al., 2014; Mancini et al., 2018).

A study conducted at Kenyatta National Hospital revealed that CUS is invaluable in diagnosing intraventricular hemorrhage (IVH) and periventricular leukomalacia (PVL), which are common in preterm babies (Muthwii et al., 2018).

A study done in South Korea investigated the prevalence of congenital brain anomalies detected by CUS in preterm babies. Their findings indicated a significant incidence of congenital PVL and hydrocephalus. The study concluded that CUS is a cost-effective and reliable tool for the early diagnosis of brain anomalies, crucial for improving neurodevelopmental outcomes in preterm babies (Lee et al., 2016).

In this study, the 30 preterm babies with IVH were sampled for doppler studies. Infants with Grade 1 IVH exhibited peak systolic volume (PSV) values ranging from 40 to 50 cm/s, with pulsatility index (PI) values between 1.3 and 1.6, indicating relatively preserved cerebral hemodynamics. Conversely, those with Grade 2 IVH showed higher PSV ranges of 60 to 73 cm/s and PI values from 1.6 to 1.9, reflecting more compromised vascular flow. Infants with Grade 4 IVH presented significantly elevated PSV values between 92 and 95 cm/s and PI values reaching up to 2.5, suggesting severe vascular compromise. Intraparenchymal hemorrhage cases presented PSV values ranging from 75 to 84 cm/s and PI values of 1.55 to 1.9, also indicating distorted cerebral vascular hemodynamics. Overall, these findings underscore the impact of varying grades of IVH on cerebral blood flow and resistance among preterm infants, necessitating close monitoring and potential intervention for those presenting with more severe vascular changes.

Some of the factors that may contribute to this pattern are such as impaired cerebral autoregulation often seen in premature infants, which makes their immature vascular systems susceptible to fluctuations in cerebral blood flow. Additionally, the fragility of cerebral blood vessels in these infants, combined with hypoxic-ischemic events,

systemic infections, and inflammation, further exacerbates the risk of IVH. These conditions can compromise endothelial integrity and disrupt normal blood flow dynamics, contributing to the observed Doppler abnormalities. (Raju et. al., 1982)

Further complicating these findings are systemic factors such as fluctuations in blood pressure and the presence of anemia, both of which can significantly impact cerebral hemodynamics. Elevated intracranial pressure (ICP) may also result from IVH, affecting cerebrovascular resistance and leading to higher PI values. Moreover, the developmental immaturity of preterm infants limits their neuroprotective mechanisms, increasing their vulnerability to vascular injuries. Understanding these underlying causes is essential for clinicians as they develop targeted interventions and management strategies to mitigate risks and improve outcomes for preterm infants at high risk of neurological complications. (Raju et. al., 1982)

5.2 Demographic factors associated with abnormal ultrasonographic findings.

5.2.1 Gestational Age

This study found that there was a significant association between gestational age and abnormal Ultrasonographic findings with a P-value of 0.002 with the highest proportion accounted for by the extremely pre-term (62.5%). The odds for an extremely preterm infant (< 28 weeks) having an abnormal scan were 0.9 times more likely.

However, it is important to appreciate the fact that gestational age alone was not an independent predictor of an abnormal outcome, in as much it is statistically significant. This implies that there was need to have other factors as well for prediction of an abnormal outcome to be true. This study can set stage for a longitudinal follow up study in the same set up.

Many times, germinal matrix/intraventricular hemorrhage are clinically silent and detected while doing routine cranial ultrasound. Some preterm babies may present with a myriad of symptoms that may be subtle such as alterations in the level of consciousness, changes in limb movement, variable muscle tone, as well as changes in eye movement. Usually, this happens within hours to days after the occurrence of the intraventricular hemorrhage. Germinal matrix/intraventricular hemorrhage can be present together with different levels of cardiac and/or respiratory distress as well as anaemia. In cases where there is extensive hemorrhage, neurodegenerative sequelae has been documented. There may be a progressive decline in cognitive function, and in some cases, with stupor, “decerebrate” posturing. Others may develop generalized tonic-clonic seizures and others may develop hypotonia. (Volpe et al., 2008)

In this study, more than half of the babies were very preterm and combined with the next largest category, extremely preterm, they accounted for more than two thirds of the babies. This would explain the large proportion with abnormal ultrasound findings.

Premature babies who develop grade III and IV germinal matrix hemorrhage/intraventricular hemorrhage, are at a significantly heightened risk of neurodevelopmental disability. This is especially so when the hemorrhage is complicated by post-hemorrhagic ventricular dilatation (PHVD), also known as ventriculomegaly, that many times needs surgical intervention. Eventual outcomes in several studies have indicated development of Cerebral palsy rates in infants with intraventricular hemorrhage grade III ranging between 7% and 63%. This goes to show that the findings have great heterogeneity (Brower et al., 2008).

In this study, the six babies who had severe IVH also presented with other neurologic findings. The two with grade IV IVH had non communicating hydrocephalus as sis

expected. Out of those two, one presented with an anterior midline abdominal defect; gastroschisis. Two out of the 6 babies with intracerebral bleeds also had PVL grade 1. All the babies with severe forms of hemorrhage listed above presented in severe disease and needed mechanical ventilation.

A study done in Nigeria in 2014, set out to determine the factors associated with IVH among preterm neonates. They carried out a prospective cross-sectional hospital-based study that included 99 infants who were not more than 37 weeks gestational age. The study found that the overall prevalence of intraventricular hemorrhage was 16.2% (16/99). Intraventricular hemorrhage was detected in 12 (33.3%) neonates between 28 and 31 weeks gestation, while 4 (6.3%) cases were seen among neonates between 32 and 36 weeks of gestation (Egwu et al., 2019). Five cases of intraventricular hemorrhage accounting for 31.3% were observed within the first 24 h of life, while 9, accounting for 56.2% were detected in preterm babies between 48 but not more than 72 hours. 2 preterm babies accounting for 12.5% of the cases were observed between 4 and 7 days of postnatal life.

Another study conducted at the Kenyatta National Hospital found that preterm infants born before 32 weeks of gestation had a significantly high risk of developing intraventricular hemorrhage. The study done in 2018 was a cohort study that recruited 195 premature babies less than or equal to 32 weeks gestational age. with a Median gestational age of 31 weeks. The median birthweight was 1440 grams. Out of the 195 respondents, 144 accounting for 73.8%, survived to day 7 of life. The overall incidence of periventricular/intraventricular hemorrhage was 8% at a 95% Confidence interval of 4 to 12% Most of the cases of hemorrhage (60%) were grade I hemorrhage while grade II hemorrhage accounted for 40%. This study revealed significant risk factors for

periventricular/intraventricular hemorrhage as being small for gestational age ($p = 0.001$), severe respiratory distress syndrome ($p = 0.005$), and being the male gender ($p = 0.035$). (Mukuria et al. 2018)

In Ethiopia, a similar study found that babies born at less than 30 weeks' gestation had a markedly higher risk of developing severe IVH compared to those born between 30 and 34 weeks (Abera, et al., 2020). The authors attributed this increased risk to the fragility of the germinal matrix and immature vascular structures in extremely preterm babies, which are prone to rupture under the stress of fluctuating cerebral blood flow.

In Uganda, a study reinforced these findings, demonstrating that the incidence of ICH was inversely proportional to gestational age. Their research revealed that babies born before 28 weeks had a significantly higher incidence of both IVH and ICH compared to those born after 28 weeks (Ndeezi, et al., 2019). Inadequate antenatal care and the lack of advanced neonatal intensive care units (NICUs) were found to be factors exacerbating the risks for these vulnerable babies.

Stoll et al. (2010) found that the incidence of severe IVH (grades III and IV) was significantly higher in infants born before 28 weeks. The OR for severe IVH in this group was 6.1 (95% CI: 4.5-8.4, $p < 0.001$), highlighting the critical need for early gestational age-specific care protocols to mitigate the risk of IVH.

In a large cohort study conducted in Sweden, it found that the incidence of severe IVH was highest among babies born before 29 weeks' gestation (Larroque, et al., 2011). They also noted that advancements in perinatal and neonatal care had led to a decline in the overall incidence of IVH, although extremely preterm babies remained at high risk.

Synnes et al. (2015), in a study conducted in Canada, showed that the risk of ICH was significantly higher in babies born before 30 weeks compared to those born between 30 and 34 weeks. This study highlighted the importance of specialized neonatal care and the use of antenatal steroids to mitigate the risks associated with extreme prematurity.

Similarly, a study conducted in India also demonstrated a clear association between lower gestational age and higher incidence of IVH. Their research indicated that babies born before 32 weeks were at a significantly higher risk for severe IVH compared to those born between 32 and 36 weeks (Shankaran, et al., 2014).

5.2.2 Birth Weight

Birth weight also had a significant association with a P-value of <0.001 with the babies weighing less than 1000 grams taking the highest proportion (70.0%). The preterm babies who weighed 1000 grams or less had an Adjusted odd's ratio of 7.3 (95% Confidence Interval 0.523 - 102.467) as compared to those weighing above 2500 grams. Birth weight was a statistically significant associated factor although not an independent predictor.

In this study just a under half of the babies had low birth weight. With addition of the Extremely low birth weight, the proportion reaches to over 60%. All the preterm babies were either very or extremely preterm. Only 5 were moderately preterm moving them to the category of small for gestational age. This makes the majority suffer the same challenges mentioned for preterm babies, having a fragile and underdeveloped neuro-architecture predisposing them to multiple challenges.

Mwaniki et al. (2014) examined the incidence of IVH among preterm infants with varying birthweights. They found that preterm babies with a birthweight of less than 1500 grams had a significantly higher odds ratio (OR = 3.7, 95% CI: 2.1-6.4) of

developing IVH compared to those with higher birthweights. The p-value for this association was less than 0.001, indicating a strong statistical significance.

In Nigeria by Olusanya et al. (2015) found that the odds of IVH were significantly higher among preterm infants with a birthweight under 1500 grams (OR = 4.2, 95% CI: 2.5-7.1, $p < 0.001$). Badoe et al. (2015), in Ghana, in a study done in a tertiary hospital setting found a high prevalence of IVH among preterm babies with low birthweight. The study emphasized the critical need for improved prenatal care and early intervention strategies to mitigate the risks associated with low birthweight and prematurity.

In Uganda, Namiro et al. (2017), highlighted similar findings, with low birthweight being a significant predictor of both IVH and ICH in preterm babies. It was pointed out that inadequate neonatal intensive care facilities and a high burden of maternal infections are major contributing factors. They recommended strengthening neonatal care services and implementing early diagnostic protocols to address these challenges.

A study done in Brazil by Guinsburg et al. (2012), found that lower birthweight was significantly associated with a higher risk of IVH. They emphasized the importance of specialized neonatal care and the use of preventive strategies, such as antenatal steroids, to reduce the risk of IVH in this population.

Chen et al. (2018), in China found that that low birthweight was a significant risk factor for both IVH and ICH. The study recommended the implementation of comprehensive neonatal care programs and the use of advanced imaging techniques for early detection and management of ICH.

Regarding the relationship between birthweight and abnormal ultrasonographic findings such as Ventriculomegaly and PVL, a Kenyan study found that low

birthweight (LBW) preterm babies had a higher incidence of both Ventriculomegaly and PVL compared to those with higher birthweights. Specifically, babies weighing less than 1500 grams had a significantly increased risk, suggesting that LBW is a critical factor in the development of these neurodevelopmental complications (Gichuru et al., 2018).

Another study done in Uganda also highlighted the link between birthweight and neonatal brain injuries. Their research indicated that preterm babies with lower birthweights were more susceptible to PVL, particularly those born before 32 weeks of gestation. The study emphasized the need for targeted interventions to reduce the risk in this group (Mwangi & Otieno, 2019).

In China, a study explored the pathways linking LBW to VM and PVL. Their study identified that oxidative stress and inflammation played significant roles in the development of these conditions among LBW preterm babies. (Zhang et al., 2016).

5.2.3 Mother's parity

According to the findings of this study, mother's parity also had significant association with a P-value of 0.024. Those who had 4 or more children accounted for 83.5% of the babies who had abnormal findings. The Odds for a mother with 3 children to have an abnormal ultrasounds scan result were 3.4 times with reference to a primiparous woman.

The association between maternal parity and the incidence of IVH in neonates has been explored in several studies, reflecting varying outcomes.

In this study, higher parity was found to be associated with having babies with intracranial anomalies picked on ultrasound. However, it is important to note that this was not as an independent predictor. It suffices to say other underlying maternal factors may also be at play.

Out of the mothers who had 3 or more pregnancies, slightly more than half had babies who had abnormal cranial ultrasound findings. Almost all of these babies who had abnormal scans, were born through spontaneous vaginal delivery. Out of those more than a third had peri-natal asphyxia related to various conditions. Some mothers had chronic conditions that were not in very good control such as severe pre-eclampsia, eclampsia and gestational diabetes that may have affected the outcome

Mungai et al. (2018), found a significant association between high parity and increased risk of IVH among preterm babies. The study, conducted in Nairobi, included 300 preterm infants, showing that multiparous women had higher odds of delivering infants with IVH (Odds Ratio of 1.75, P. Value of 0.04).

Another cross-sectional study done in the United States by Lee et al. (2017) included 1,200 preterm infants and found that higher parity was associated with an increased risk of IVH with the Odds Ratio of 2.3, and a statistically significant P. value of = 0.01).

Stoll et al. (2010), found that both primiparous mothers and multiparous mothers exhibited different risk profiles for preterm birth and associated complications like IVH. Primiparous mothers were often associated with a higher risk of preterm delivery, which is a known risk factor for IVH, thus indirectly linking maternal parity to the incidence of this hemorrhage.

In contradiction, Linder et al. (2017), observed that babies born to primiparous mothers had a higher incidence of severe IVH compared to those born to multiparous mothers. This study suggested that the physiological and obstetric factors unique to first-time pregnancies could contribute to the increased vulnerability of neonates to IVH.

Gagliardi et al. (2009), reported that higher maternal parity was associated with a reduced risk of IVH in preterm babies. This protective effect was hypothesized to result from the improved uterine environment and more efficient placental function in subsequent pregnancies, reducing the incidence of preterm birth and its complications. These findings point to the complex interplay between maternal parity and neonatal outcomes, necessitating further investigation.

Ghi et al. (2018), found that higher parity was correlated with an increased risk of ventriculomegaly. It highlighted the importance of considering maternal reproductive history, in particular parity, when assessing the risk of ventriculomegaly in pregnancies. It involved a large cohort and controlled for various confounding factors, providing robust evidence of the association between maternal parity and ventriculomegaly.

The mechanisms by which maternal parity might influence the development of ventriculomegaly were described as complex and multifactorial. According to a review by Salihu et al. (2016), higher parity was associated with increased maternal age and greater exposure to pregnancy-related physiological changes. These factors contributed to complications such as placental insufficiency and altered fetal development, potentially leading to conditions like ventriculomegaly.

Kinzler et al. (2017), reported no significant correlation between parity and the occurrence of ventriculomegaly. This study suggested that other factors, such as genetic predispositions and environmental influences, might play a more significant role in the development of ventriculomegaly. The discrepancies between studies highlight the need for further research to clarify the relationship between maternal parity and ventriculomegaly.

Some studies have indicated that higher maternal parity may be associated with an increased risk of Periventricular Leukomalacia (PVL). A study by Spinillo et al. (1998), found that multiparous women had a higher incidence of delivering preterm babies with PVL compared to primiparous women. They found that uterine overdistention, often seen in multiparous women, could lead to adverse perinatal outcomes, including PVL, due to compromised placental function and increased susceptibility to infections.

In contrast, Drost et al. (2008), In a meta-analysis that included cohort, case-control studies and randomized controlled trials examined a large cohort of preterm babies and found no significant difference in the incidence of PVL between babies born to primiparous and multiparous mothers. This review suggested that factors such as the gestational age at delivery and the presence of other perinatal complications might play a more critical role than parity alone in the development of PVL.

A review by Stoll et al. (2010), explored multiple maternal and neonatal risk factors for PVL. It highlighted that while higher parity was observed in mothers of babies with PVL, it was often confounded by other variables such as maternal age, socioeconomic status, and access to prenatal care and that it was important to control for confounding factors when evaluating the impact of maternal parity on PVL risk.

5.3 Study Limitations

The study setting was a tertiary level facility with different levels of technical staff and equipment that cannot be reproduced in smaller settings.

The study would have been best done over a longer period to allow the inclusion of more participants. A longer duration would also include the ability for follow-up to be able to see the eventual outcomes after discharge from the facility.

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

1. More than a third (36.2%) of the babies had abnormal cranial ultrasound findings, the commonest being intracranial hemorrhage followed by ventriculomegaly. The main type of hemorrhage was intraventricular followed by intracerebral.
2. Low gestational age, low birth weight of preterm babies and increased mothers' parity was associated negatively with abnormal cranial ultrasound findings but not as independent predictors.

6.2 RECOMMENDATION

1. To ensure every preterm infant less than 32 weeks gestational age or less than 1500 grams has access to a routine cranial ultrasound. These may include strategies that flag and prioritize the babies at risk to ensure that none are missed.
2. Special attention to be paid to multiparous mothers for screening of their preterm babies.
3. There is need for further studies to explore the relationship between parity and abnormal cranial ultrasound findings.

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APPENDICES

Appendix 1: Cranial Ultrasound Procedure and Considerations

The anterior fontanelle and the posterior fontanelle serve as the main acoustic windows. The mastoid fontanelle, the squamous temporal bone, the foramen magnum, and the coronal suture can all be used as supplementary acoustic windows.

Two transducers can be used. A 7.5-8 MHz micro convex/ for the deeper structures and a linear transducer, usually 11-12 MHz, can be used for superficial structures. (Caro-Domínguez et al., 2021)

Procedure

A good Cranial ultrasound that is normal should have more than twenty images ideally. Using the curvilinear probe, six images are taken in the coronal plane through the anterior fontanelle. In the sagittal plane, five images are taken through the anterior fontanelle. Lastly, two images of the posterior fossa are taken through the mastoid fontanelle.

Coronal areas of focus (6 or more images):

- Anterior (distal) to frontal horns of lateral ventricles
- The level of the anterior horns of lateral ventricles or at the level of the Sylvian fissures
- level of the 3rd ventricle and thalamus bilaterally
- level of the posterior horns of lateral ventricles, visualize choroids.
- Posterior to choroids (posterior brain substance)

• Sagittal areas of focus (5 or more images):

- Midline through third ventricle, septum cavum pellucidum, cerebellum with 4th ventricle and foramen magnum
- Through each lateral ventricle showing anterior and posterior horns.
- Lateral to the ventricle for deep white matter through the cerebral hemispheres.

Borrowed from (*“AIUM Practice Parameter for the Performance of Neurosonography in Neonates and Infants,” 2020*)

Appendix 2: Gantt Chart on Study Timelines

	April to May 2022	June 2022 to February y 2023	April to July 2023	Sept 2023 to Feb 2024	Mar to June 2024	July 2024 to Septem ber 2024
Concept paper development						
Presentation of concept paper to the department						
Development of proposal						
Submission of proposal to IREC for review						
Pretest/ pilot study						
Data collection and Analysis						
1 st draft thesis correction with supervisors and subsequent drafts						
Submission and defense						
Final bounds drafts (for library) and dissemination of findings						

Appendix 3: Budget for the study

NO.	STUDY ITEMS	QUANTITY	COST PER UNIT IN KSHS	TOTAL COST KSHS
A.	Stationery and Equipment			
1	Printing papers	16 reams	@ 400	6,400
2	Ball point pens	1 packet	@ 1000	1,000
3	Flash disk & Compact Disc	2 + 6, respectively	@ 2000 & 50	4,300
4	Files	5	@ 500	250
5	Pencils	5	@ 30	150
6	Erasers	5	@ 20	100
7	Notebooks	3	@ 350	1,050
8	Stapler & staples	1 & 1 Packet, respectively	@ 500 & 300	800
B.	Development of Thesis			
9	Printing of drafts	40 pages (x 8 copies)	20/page	6,400
10	Printing & binding final	3 copies	3000/copy	9,000
11	Pilot/pre-test of tools			15,000
C.	Fieldwork			
12	Research assistant	1 (50 questionnaires)	@200	10,000
D.	Communication & Analysis			
13	Phone & Internet	-	-	10,000
14	Biostatistician consultations (statistician/Analysis)	-	-	50,000
15	Dissemination costs	-	-	30,000
E.	Thesis Development			
16	Printing of draft thesis	60 pages (x 10 copies)	30/page	18,000
17	Final printing & binding (hard)	60 pages (x4 copies)	30/page	18,000
18	Miscellaneous (10%)	-	@10%	18,400
Grand Total				198,850

Appendix 3: Informed Consent Form

English Version

Investigator:

NAME: Dr. Crispus Adalla Sala (KMPDC REG. NO A9508)

I am a resident pursuing a master's degree in Radiology and Imaging at Moi University. I would like to recruit you or your kin into my study which is to study cranial ultrasonographic features in neonates.

Purpose: This study will seek to describe the correlation between ultrasonographic features among neonates having routine Cranial Ultrasounds done alongside their clinical condition.

Procedure: All mothers who have neonates at the Newborn unit and who will provide informed consent will have their babies assessed. In line with their routine clinical management, a Cranial ultrasound examination was done after application of ultrasound gel. Participants were interviewed for biodata and clinical examination was carried out and recorded on data collection forms. Data that has been collected shall remain confidential during the study and participants' identities shall never at any point be disclosed.

Benefits: Participants will have no benefits in this research and will receive similar clinical care to other patients.

Risks: There will be no foreseen risks to the respondents that may be as a result of this study.

Confidentiality: Information collected in this research shall remain confidential and that there will be no disclosure whatsoever of any information exposing any individual.

Rights to Refuse: Should a participant decline to participate or have a change of mind; they can pull out from the study at any time.

This study has been approved by the Institutional Research and Ethics Committee (IREC) of Moi University/Moi Teaching and Referral Hospital.

Next of Kin signature: Investigator:

Date:.....

Kiswahili Version

Mpelelezi:

Jina : Dkt Crispus Adalla Sala (Nambari ya Usajili A9508)

Kwa wakati huu, natafuta shahada ya uzamili katika Radiology na Imaging katika Chuo Kikuu cha Moi. Ningependa kukuhusisha katika utafiti wangu ambao utajaribu kuonyesha matokeo ya picha ya ultrasound ya Ubongo na jinsi inavyolingana na hali ya ugonjwa wa mtoto.

Kusudi: Utafiti huu utajaribu kueleza jinsi picha ya ultrasound ya Ubongo na jinsi inavyolingana na hali ya ugonjwa ya mtoto katika chumba cha watoto wachanga wasiozidi umri wa wiki sita hapa hospitali ya MTRH.

Utaratibu: Wamama wote walio na mtoto katika chumba cha watoto wachanga wasiozidi umri wa wiki sita, watasajiliwa katika utafiti huu baada ya kuombwa ruhusa rasmi. Baadaye wataonekana na kifaa maalum ya ultrasound kwa kuweka kipima kwenye kichwa baada ya kupaka mafuta aina ya jeli. Kwa watoto watakaosajiliwa, wamama wao pia watahojiwa kuhusu matatizo mengine yoyote ya wanao. Mahojiano yata rekodiwa kwenye makaratasi ya utafiti. Utambulizi wa wagonjwa waliohusika utawekwa siri.

Faida: Kutakuwa hakuna faida moja kwa moja ya kushiriki katika utafiti huu. Wanaofanyiwa utafiti watakuwa nahaki nakupewa ubora sawa na wale ambao hawatofanyiwa utafiti huo.

Hatari: Hakuna hatari ya kutarajia kwa washiriki inatokana na utafiti huu.

Usiri: Habari zote zilizopatikana katika utafiti huu wa kutibiwa zitawekwa kwa usiri mkubwa na wala haitatolewa kwa mtu yeyote asiye husika na utafiti.

Haki ya kukataa: Kushiriki katika utafiti huu ni hiari yako, kuna uhuru wa kukataa kuchukua sehemu au kutoka wakati wowote. Utafiti huu imekuwa kupitishwa na Utafiti wa Taasisi na Kamati ya Maadili (IREC) ya Chuo Kikuu cha kufundishia Moi na Hospitali ya Rufaa.

Sahihi la Mlezi:

Sahihi la Mpelelezi:

Tarehe:

Appendix 4: Questionnaire

Demographics

Date: Hospital Number:

Gestational Age: Serial Number

Gender: Male Female: County of Residence

MOTHER'S DETAILS

Parity:

BIRTH DETAILS

Child's Place of birth: Home Hospital Other(specify)

Gestational Age at birth:

Extremely preterm (less than 28wks) Very preterm (less than 32 weeks)

Moderately to late preterm (33-<37wks)

Mode of Delivery:

Normal delivery SVD
Induced Labour

Caesarian Section
Assisted Delivery

Birth Weight:

<750g 750-1000g 1000g-1500g 1500-2500g >2500g

CLINICAL CONDITIONS

Convulsions

Hotness of the body

Hypotonia

Increased Head Circumference

Neonatal infection

Cephalohematoma

Birth Asphyxia

Spinal Anomalies

Other (Specify)

ULTRASONOGRAPHIC FINDINGS

HEMORRHAGE

GM-IVH

- Grade I - restricted to the GM
- grade II -spread to the lateral ventricles but occupies less than 50% of the ventricles
- Grade III- hemorrhage occupying more than 50% of ventricle and with ventricular dilatation
- grade IV - hemorrhage extending to nearby parenchyma

Intracerebral Bleed

VENTRICULOMEGALLY

- mild/borderline - between 10-12 mm
- moderate - 12.1-15 mm
- severe (also known as hydrocephalus) - >15 mm

PERIVENTRICULAR LEUKOMALACIA

- grade 1: periventricular echogenicity without cyst > 7 days
- grade 2: small periventricular cysts
- grade 3: extensive periventricular cysts in occipital & frontoparietal
- grade 4: deep white matter involvement with extensive subcortical cysts.....

CONGENITAL ANOMALIES

- aqueductal stenosis
- Chiari malformations
- neural tube defect(s)
- Dandy-Walker malformation
- Encephalocele
- alobar holoprosencephaly
- posterior fossa cysts
- polymicrogyria
- Other (specify)

INFECTION PATTERNS

- Cerebritis
- Ventriculitis
- Meningitis

Appendix 5: Ballard's score

MATURATIONAL ASSESSMENT OF GESTATIONAL AGE (New Ballard Score)

NAME _____ SEX _____
 HOSPITAL NO. _____ BIRTH WEIGHT _____
 RACE _____ LENGTH _____
 DATE/TIME OF BIRTH _____ HEAD CIRC. _____
 DATE/TIME OF EXAM _____ EXAMINER _____
 AGE WHEN EXAMINED _____
 APGAR SCORE: 1 MINUTE _____ 5 MINUTES _____ 10 MINUTES _____

NEUROMUSCULAR MATURITY

NEUROMUSCULAR MATURITY SIGN	SCORE							RECORD SCORE HERE
	-1	0	1	2	3	4	5	
POSTURE								
SQUARE WINDOW (Wrist)								
ARM RECOIL								
POPLITEAL ANGLE								
SCarf SIGN								
HEEL TO EAR								
TOTAL NEUROMUSCULAR MATURITY SCORE								

SCORE

Neuromuscular _____
 Physical _____
 Total _____

MATURITY RATING

SCORE	WEEKS
-10	26
-5	22
0	24
5	26
10	28
15	30
20	32
25	34
30	36
35	38
40	40
45	42
50	44

PHYSICAL MATURITY

PHYSICAL MATURITY SIGN	SCORE							RECORD SCORE HERE
	-1	0	1	2	3	4	5	
SKIN	sticky friable transparent	gelatinous red translucent	smooth pink visible veins	superficial peeling & / or rash, few veins	cracking pale areas rare veins	parchment deep cracking no vessels	leathery cracked wrinkled	
LAMUGO	none	sparsely	abundant	thinning	bald areas	mostly bald		
PLANTAR SURFACE	heel-toe 40-50 mm -1 <40 mm -2	>50 mm no crease	faint red marks	anterior transverse crease only	creases ant. 2/3	creases over entire sole		
BREAST	imperceptible	barely perceptible	flat areola no bud	stippled areola 1-2 mm bud	raised areola 3-4 mm bud	full areola 5-10 mm bud		
EYE / EAR	lids fused loosely -1 tightly -2	lids open pinna flat stays folded	sl. curved pinna; soft; slow recoil	well-curved pinna; soft but ready recoil	formed & firm instant recoil	thick cartilage ear ruff		
GENITALS (Male)	scrotum flat, smooth	scrotum empty faint rugae	testes in upper canal rare rugae	testes descending few rugae	testes down good rugae	testes pendulous deep rugae		
GENITALS (Female)	clitoris prominent & labia flat	prominent clitoris & small labia minora	prominent clitoris & enlarging minora	majora & minora equally prominent	majora large minora small	majora cover clitoris & minora		
TOTAL PHYSICAL MATURITY SCORE								

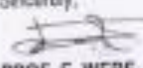
Reference

Ballard JL, Khoury JC, Wedig K, et al. New Ballard Score, expanded to include extremely premature infants. J Pediatr 1991; 119:417-423. Reprinted by permission of Dr Ballard and Moby—Year Book, Inc.

GESTATIONAL AGE (weeks)

By dates _____
 By ultrasound _____
 By exam _____

Appendix 6: IREC Approval

 MTRH-MU-INSTITUTIONAL RESEARCH AND ETHICS COMMITTEE (IREC) MOI TEACHING AND REFERRAL HOSPITAL P.O. BOX 3 ELDORET Tel: 334718/3	 MOI UNIVERSITY COLLEGE OF HEALTH SCIENCES P.O. BOX 4006 ELDORET Tel: 334718/3 25 th August, 2023																					
Reference: IREC/497/2023 Approval Number: 0004535																						
Dr. Crispus Adalia Sala, Moi University, School of Medicine, P.O. Box 4806-30100, <u>ELDORET-KENYA.</u>																						
Dear Dr. Sala,																						
<u>PATTERNS OF ROUTINE CRANIAL ULTRASOUND FINDINGS AMONG PRETERMS ALONGSIDE CLINICAL CONDITION AT MOI TEACHING AND REFERRAL HOSPITAL.</u>																						
This is to inform you that MTRH/MU-IREC has reviewed and approved the above referenced research proposal. Your application approval number is FAN: 0004535 . The approval period is 25th August, 2023- 24 August, 2024 . This approval is subject to compliance with the following requirements:																						
i. Only approved documents including (informed consents, study instruments, Material Transfer Agreements (MTA) will be used. ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by MTRH/MU-IREC. iii. Death and life threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to MTRH/MU-IREC within 72 hours of notification. iv. Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to MTRH/MU-IREC within 72 hours. v. Clearance for export of biological specimens must be obtained from MOH at the recommendation of NACOSTI for each batch of shipment. vi. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal. vii. Submission of an executive summary report within 90 days upon completion of the study to MTRH/ MU-IREC.																						
Prior to commencing your study, you will be required to obtain a research license from the National Commission for Science, Technology and Innovation (NACOSTI) https://oris.nacosti.go.ke and other relevant clearances from study sites including a written approval from the CEO-MTRH which is mandatory for studies to be undertaken within the jurisdiction of Moi Teaching & Referral Hospital (MTRH) and its satellites sites.																						
Sincerely,  PROF. E. WERE CHAIRMAN INSTITUTIONAL RESEARCH AND ETHICS COMMITTEE		<table border="0"> <tr> <td>cc</td> <td>CEO</td> <td>-</td> <td>MTRH</td> <td>Dean</td> <td>-</td> <td>SOP</td> <td>Dean</td> <td>-</td> <td>SOM</td> </tr> <tr> <td></td> <td>Principal</td> <td>-</td> <td>CHS</td> <td>Dean</td> <td>-</td> <td>SON</td> <td>Dean</td> <td>-</td> <td>SOD</td> </tr> </table>	cc	CEO	-	MTRH	Dean	-	SOP	Dean	-	SOM		Principal	-	CHS	Dean	-	SON	Dean	-	SOD
cc	CEO	-	MTRH	Dean	-	SOP	Dean	-	SOM													
	Principal	-	CHS	Dean	-	SON	Dean	-	SOD													

Appendix 7: MTRH Approval



MOI TEACHING AND REFERRAL HOSPITAL

Telephone: (+254)-0532065471/2/3/4
 Fax: 0532061749
 Email: ceo@mtrh.go.ke/ceosoffice@mtrh.go.ke

NANHE ROAD
 P.O. BOX 3-30100
 ELDORET, KENYA

Ref: ELD/MTRH/R&P/10/2/V.2/2010

25th August, 2023

Dr. Crispus Adalla Sala,
 Moi University,
 School of Medicine,
 P.O. Box 4606-30100,
 ELDORET-KENYA.

PATTERNS OF ROUTINE CRANIAL ULTRASOUND FINDINGS AMONG PRETERMS ALONGSIDE CLINICAL CONDITION AT MOI TEACHING AND REFERRAL HOSPITAL

You have been authorised to conduct research within the jurisdiction of Moi Teaching and Referral Hospital (MTRH) and its satellites sites. You are required to strictly adhere to the regulations stated below in order to safeguard the safety and well-being of staff, patients and study participants seen at MTRH.

- 1 The study shall be under Moi Teaching and Referral Hospital regulation.
- 2 A copy of MTRH/MU-IREC approval shall be a prerequisite to conducting the study.
- 3 Studies intending to export human bio-specimens must provide a permit from MOH at the recommendation of NACOSTI for each shipment.
- 4 No data collection will be allowed without an approved consent form(s) to participants unless waiver of written consent has been granted by MTRH/MU-IREC.
- 5 Take note that data collected must be treated with due confidentiality and anonymity.

The continued permission to conduct research shall only be sustained subject to fulfilling all the requirements stated above.

The approval period is 25th August, 2023 – 24th August, 2024.

Done 27/8/2023
DR. WILSON K. ARUMASA, MRS, EBS
CHIEF EXECUTIVE OFFICER

- C.C. - Senior Director, Clinical Services
 - Director, Nursing Services
 - HOD, HRISM



All correspondences should be addressed to the Chief Executive Officer

Visit our Website: www.mtrh.go.ke

TO BE A GLOBAL LEADER IN THE PROVISION OF EXCEPTIONAL MULTI-SPECIALTY HEALTH CARE, TRAINING AND RESEARCH

Appendix 8: NACOSTI Approval

 REPUBLIC OF KENYA Ministry of Science, Technology and Innovation Ref No: 214838	 NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION Date of Issue: 24/February/2024
RESEARCH LICENSE	
	
This is to Certify that Dr. Cansus Adaka Sala of Moi University, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev. 2014) in Uasin-Gishu on the topic: PATTERNS OF ROUTINE CRANIAL ULTRASOUND FINDINGS AMONG PRETERMS ALONGSIDE CLINICAL CONDITION AT MOI TEACHING AND REFERRAL HOSPITAL for the period ending : 24/February/2025.	
License No: NACOSTI/24/33387 21-4838 Applicant Identification Number	Director General NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION Verification QR Code 
NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application. See overleaf for conditions	