"GENERAL MOVEMENT ASSESSMENT IN TERM NEONATES WITH PERINATAL ASPHYXIA TO PREDICT NEURODEVELOPMENTAL OUTCOME- A LONGITUDINAL STUDY"

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ABBREVIATIONS

CP**	–	Cerebral Palsy
GMA	–	General Movements Assessment
HIE	–	Hypoxic-Ischemic Encephalopathy
MRI	–	Magnetic Resonance Imaging
MOS-R**	–	Motor Optimality Score-Revised
PR**	–	Poor Repertoire
CS**	–	Cramped Synchronized
Ch**	–	Chaotic
FM**	–	Fidgety Movements
WHO**	–	World Health Organization
IAP**	–	Indian Academy of Pediatrics
APGAR**	–	Appearance, Pulse, Grimace, Activity, and Respiration (a scoring system to assess newborns)
GM**	–	General Movements
GMA**	–	General Movements Assessment
CP**	–	Cerebral Palsy
HINE**	–	Hammersmith Infant Neurological Examination
SPSS**	–	Statistical Package for the Social Sciences
IBM**	–	International Business Machines
NICU	–	Neonatal Intensive Care Unit
ABC	–	Airway, Breathing, Circulation
ABG	–	Arterial Blood Gas
AGA	–	Appropriate for Gestational
BP	–	Blood Pressure

CBC	–	Complete Blood Count
CPAP	–	Continuous Positive Airway Pressure
CSF	–	Cerebrospinal Fluid
EEG	–	Electroencephalogram
FiO_2	–	Fraction of Inspired Oxygen
HR	–	Heart Rate
ICH	–	Intracranial Hemorrhage
ICU	–	Intensive Care Unit
IV	–	Intravenous
LGA	–	Large for Gestational Age
LP	–	Lumbar Puncture
MRI	–	Magnetic Resonance Imaging
NEC	–	Necrotizing Enterocolitis
PEEP	–	Positive End-Expiratory Pressure
PPHN	–	Persistent Pulmonary Hypertension of the Newborn
RDS	–	Respiratory Distress Syndrome
RR	–	Respiratory Rate
SGA	–	Small for Gestational Age
TPN	–	Total Parenteral Nutrition
IVH**	–	Intraventricular Hemorrhage
MIT-PB**	–	Movement Imitation Therapy for Preterm Babies
RCT**	–	Randomized Controlled Trial
SNP**	–	Structured Neonatal Physical Therapy
NAPI**	–	Neurobehavioral Assessment of Preterm Infants
Kappa**	–	Kappa Coefficient (a measure of inter-rater reliability)

pH**	–	Potential of Hydrogen (referring to blood pH level)
LSCS	–	Lower segment cesarean section
NVD	–	Normal Vaginal delivery

ABSTRACT

Background: Perinatal asphyxia is a leading cause of neonatal morbidity and mortality, particularly in low-resource settings like India, with an incidence of 2–10 per 1000 term births. It is a significant contributor to hypoxic-ischemic encephalopathy (HIE) and cerebral palsy (CP). Early prediction of neurodevelopmental outcomes remains challenging, especially in regions with limited access to advanced diagnostic tools. Prechtl's General Movements Assessment (GMA) offers a non-invasive, cost-effective method for early identification of high-risk infants.

Objective: This study aimed to evaluate the quality of general movements in term neonates with perinatal asphyxia and predict their neurodevelopmental outcomes using GMA and the Motor Optimality Score-Revised (MOS-R).

Methods: A longitudinal study was conducted on 60 term neonates (37–42 weeks gestation) with perinatal asphyxia admitted to a tertiary care hospital. Infants were assessed at discharge and 3 months of age using GMA and MOS-R. Data on neonatal resuscitation, Sarnat staging, APGAR scores, NICU stay, and therapeutic interventions were analyzed. Statistical analysis included chi-square tests, Kruskal-Wallis tests, and McNemar tests.

Results: Infants with normal GMA at discharge had optimal MOS-R scores (100%), while those with cramped synchronous movements exhibited severely reduced outcomes (100%). Significant associations were found between poorer MOS-R scores and factors such as intensive resuscitation (intubation: 81.8% moderately reduced), moderate/severe Modified Sarnat staging (78.6–100% impaired), prolonged NICU

stay (23 ± 19 days in severely reduced), and low APGAR scores (≤3). Therapeutic cooling and anti-epileptic use were also linked to adverse outcomes.

Conclusion: GMA is a reliable tool for early prediction of neurodevelopmental impairments in asphyxiated neonates. Abnormal movements, particularly cramped synchronous patterns, strongly correlate with poor outcomes. Integration of GMA into neonatal care protocols can facilitate timely interventions, especially in resource-limited settings.

Keywords: Perinatal asphyxia, Hypoxic-ischemic encephalopathy (HIE), Cerebral palsy (CP), Prechtl's General Movements Assessment (GMA), Motor Optimality Score-Revised (MOS-R), Neurodevelopmental outcomes, Term neonates, Early intervention, Neonatal resuscitation, Sarnat staging.

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INTRODUCTION

Perinatal asphyxia is a lack of blood flow or gas exchange to or from the fetus in the period immediately preceding, during, or following birth. Perinatal asphyxia can have serious systemic and neurological consequences because it reduces blood flow and/or oxygen to a fetus or child during the peripartum period. When placental (prenatal) or pulmonary (immediate postnatal) gas exchange is impeded or ceases entirely, the critical organs experience partial (hypoxia) or complete (anoxia) oxygen deficiency. This causes gradual hypoxemia and hypercapnia. If hypoxemia is severe enough, tissues and important organs (muscle, liver, heart, and eventually the brain) will suffer an oxygen deficit. Anaerobic glycolysis and lactic acidosis will occur. Neonatal hypoxic-ischemic encephalopathy refers to the neurological consequences of prenatal hypoxia(1).

Perinatal asphyxia affects 2 to 10 out of every 1000 neonates born at term, and even more for preterm babies. According to the World Health Organization, birth asphyxia causes 4 million neonatal fatalities per year, accounting for 38% of all deaths among children under the age of five. Perinatal asphyxia deaths continue to be high in underdeveloped nations, and continuously monitoring risk variables will assist improve outcomes in these situations. The diagnostic criteria for neonatal hypoxic-ischemic encephalopathy are listed below(2):

- Metabolic acidosis with pH <7.0 (in umbilical cord or infant blood sample)
- Base Deficit -12
- APGAR score = five at 10 minutes with a continued need for resuscitation

- Presence of multiple organ-system failures
- Signs of encephalopathy include hypotonia, irregular eye or pupil movements, weak or absent suction, apnea, hyperpnea, or clinical seizures.
- Higher Cord blood lactate level.

It is a well-known cause of developmental problems, including cerebral palsy (CP); nevertheless, the majority of CP cases are not caused by an interruption in oxygen flow around birth(2). In addition, many children born with perinatal asphyxia develop abnormally. To far, it is unclear which children born with asphyxia will have neurological damage. Recently developed imaging modalities of the newborn brain, such as diffusion weighted MRI and magnetic resonance spectroscopy, show promise in this regard, but they are not widely available in secondary paediatric settings. Perinatal asphyxia is still difficult to predict in a more general pediatric environment(3).

Perinatal asphyxia affects 2 to 10 out of every 1000 neonates born at term, and even more for preterm babies(4). According to WHO, birth asphyxia causes 4 million neonatal deaths annually, accounting for 38% of all child deaths under the age of five. Assessing risk factors for prenatal asphyxia is crucial for improving outcomes in underdeveloped nations, where fatalities remain high(5).

The Prechtl General Movement Assessment (GMA) is highly predictive of neurodevelopmental outcomes in preterm and term infants with risk factors. The GMA permits the early detection of newborns who are at a higher risk of cerebral palsy. The assessment is based on visual Gestalt perception of videoed age-specific

normal and aberrant movement patterns, and it is non-invasive, inexpensive, and extremely reliable, with inter-scorer reliability values ranging from 89 to 93%(5).

General Movements (GMs) are spontaneous movements with a diverse and complex repertoire and a distinct spatial-temporal organization. GMs can be observed from early fetal development until 4-5 months post-term, when purposeful and antigravity movements predominate. GMs affect the entire body and manifest as a varying sequence of arm, leg, neck, and trunk movements. They come and go gently, with varying intensities and speeds. Rotations and many minor variations in direction of motion give them a complex and smooth appearance(5).

From term age to the second month post-term, GMs take the form of "writhing movements". They are extremely similar to preterm-age GMs, but with a lower amplitude and speed(2,6,7). Preterm GMs and writhing movements are categorized as normal or aberrant, with deficient repertory (PR), cramped synchronized (CS), or chaotic (Ch) GMs(6,7). CS GMs have a particularly high predictive value (70% sensitivity and 97% specificity) for spastic cerebral palsy. They are distinguished by rigidity, a lack of fluency and elegance, and the nearly synchronous contraction and relaxation of limb and trunk muscles. Infants with Ch GMs develop CS GMs around term and are at high risk for spastic cerebral palsy. PR GMs, on the other hand, are less predictive and more unspecific(1,4). GMA has a higher sensitivity (97-98%) and specificity (89-91%) than cranial ultrasonography (74% and 92%, respectively) and neurological examination (88% and 87%, respectively), but it is comparable to magnetic resonance imaging performed at term age(5,8). Although writhing motions have a little lower sensitivity (93%) and specificity (59%)14 than fidgety movements (FM), identifying aberrant GMs, particularly CS, which can last until FM's phase and suggest a worse prognosis, is equally crucial(9,10). This makes GMA a critical tool

for early detection of neurodevelopmental damage, providing justification for early intervention and the desired minimizing of sequelae(9,10).

This study was aimed at predicting neuro developmental outcome in term neonates withbirth asphyxia. The study used a non-invasive method of evaluating general movements through digital recording of general movements to define a pattern and study any abnormalities(11).

Outline of thesis

This dissertation examines the changes in General Movements Assessment (GMA) and Motor Optimality Score-Revised (MOS-R) in high-risk newborns, notably those who survived with perinatal hypoxia using clinical assessment and observational analysis. The study primarily focuses on evaluating the potential of GMA and MOS-R as predictive tools for diagnosing, assessing the severity, and predicting the progression of neurodevelopmental disorders such as cerebral palsy (CP). After providing a detailed description of the materials and methods used for data collection and analysis, the results are presented, followed by a discussion of their clinical implications. The findings of the study are summarized, highlighting their significance and potential impact on early intervention strategies, with recommendations for future research and further exploration of GMA and MOS-R's role in improving neurodevelopmental outcomes. Finally, the references and appendices offer additional context and support to the study, ensuring a comprehensive understanding of the topic(4,11).

AIMS AND OBJECTIVES

AIM:

To evaluate the quality of general movements in surviving term neonates with perinatal asphyxia and predict their neurodevelopmental outcomes using Prechtl's General Movements Assessment.

Research Objectives:

Primary Objective:

To assess the general movements at the time of discharge and at 3months of age in surviving term neonates with perinatal asphyxia.

Secondary Objective:

To predict the neurodevelopmental outcome in term neonates with perinatal asphyxia by comparing the general movement assessment at discharge and at 3 months of age.

REVIEW OF LITERATURE

Prevalence of Perinatal Asphyxia and Hypoxic-Ischemic Encephalopathy (HIE) in India

Perinatal asphyxia is a significant public health issue in India, with a high prevalence compared to developed countries. Studies indicate that perinatal asphyxia occurs in 2 to 10 per 1000 term births and is even higher in preterm infants (National Neonatology Forum, 2003). Hypoxic-Ischemic Encephalopathy (HIE), a neurological consequence of perinatal asphyxia, is a leading cause of neonatal mortality and morbidity in India. According to the World Health Organization (WHO), birth asphyxia accounts for 38% of under-five child mortality worldwide, with a disproportionate impact in poor countries such as India(4). In India, the prevalence of HIE is reported to be 20-30% among newborns with birth asphyxia, underscoring the urgency of early detection and care(12). Perinatal asphyxia remains a leading cause of infant illness and mortality in India, with a higher prevalence than in developed nations. Several Indian research have revealed the prevalence of prenatal hypoxia and its effects on newborn health outcomes(13).

The prevalence of perinatal asphyxia in India ranges from 5.9 to 9.1 per 1000 live births, with higher rates observed in rural and community-based settings(7). Hypoxic-Ischemic Encephalopathy (HIE) is a common complication, affecting 20-30% of asphyxiated neonates, with mortality rates ranging from 12-20% (National Neonatology Forum, 2003)(1). Risk factors include maternal anemia, protracted labor, meconium-stained amniotic fluid, and low birth weight. These findings highlight the critical need for improved prenatal and intrapartum care in India to lower the prevalence of perinatal asphyxia.

Definition of Birth Asphyxia

The World Health Organization (WHO) defines birth asphyxia as the inability to initiate and sustain breathing at birth, resulting in hypoxia and hypercapnia (Black et al., 2010)(1). The Indian Academy of Pediatrics (IAP) defines it as an umbilical cord blood pH of <7.0 or a base deficit of ≥12 mmol/L, combined with clinical indications of encephalopathy including hypotonia, seizures, or impaired reflexes (National Neonatology Forum, 2003)(7).

Both definitions emphasize the importance of biochemical and clinical criteria for diagnosis. Additionally, studies have highlighted the role of Apgar scores in diagnosing birth asphyxia, with scores of ≤5 at 10 minutes being a key indicator (Committee on Fetus and Newborn, American Academy of Pediatrics, 1996)(6). Clinical signs of encephalopathy, such as abnormal pupillary movements, weak suck, and seizures, are also critical for diagnosis(10). These diagnostic criteria are essential for identifying neonates at risk of hypoxic-ischemic encephalopathy (HIE) and other long-term neurodevelopmental impairments(10).

Birth asphyxia is a critical neonatal condition characterized by the failure to initiate and sustain breathing at birth, leading to hypoxia (lack of oxygen) and hypercapnia (excess carbon dioxide) in the newborn(12). According to the World Health Organization (WHO), birth asphyxia is defined as the failure to establish spontaneous respiration at birth, often accompanied by low Apgar scores (≤5 at 10 minutes) and the need for prolonged resuscitation(13). The World Health Organization underlines that birth asphyxia is a prominent cause of infant mortality and morbidity, especially in low- and middle-income countries(10).

The Indian Academy of Pediatrics (IAP) offers a more complete definition that includes both biochemical and clinical criteria. The IAP defines birth asphyxia as an umbilical cord blood pH <7.0 or a base deficit of ≥12 mmol/L, accompanied with clinical symptoms of neonatal encephalopathy including hypotonia, convulsions, or impaired reflexes (National Neonatology Forum, 2003). The IAP emphasizes the significance of Apgar scores in detecting birth asphyxia, with values of ≤5 at 10 minutes being a critical indicator (American Academy of Pediatrics, 1996)(14).

Both definitions emphasize the importance of early diagnosis and intervention to prevent long-term complications such as Hypoxic-Ischemic Encephalopathy (HIE) and cerebral palsy (CP)(10). The WHO and IAP definitions are widely used in clinical practice to identify neonates at risk of adverse outcomes and guide appropriate management strategies.

Morbidity of Surviving Children with Birth Asphyxia in India

Children who survive birth hypoxia frequently experience long-term neurodevelopmental problems, with cerebral palsy (CP) being one of the most severe.

Studies from India report that 10-20% of children with Hypoxic-Ischemic Encephalopathy (HIE) develop CP, with symptoms typically appearing within the first two years of life . Delayed diagnosis and lack of early intervention exacerbate the morbidity, leading to lifelong disabilities such as motor impairments, cognitive deficits, and epilepsy (Agrawal et al., 2012)(14). For instance, a study that infants with severe HIE had a 50-60% risk of developing CP, with many also experiencing intellectual disabilities and seizures. Similarly, Modified(7) highlighted that neonates with moderate to severe HIE often exhibit abnormal muscle tone, poor feeding, and delayed milestones, which are early indicators of CP(14).

In India, the burden of CP is exacerbated by restricted access to early diagnostic tools and rehabilitation programs. A National Neonatology Forum (2003)(15) study found that early detection and intervention can dramatically improve outcomes for children with cerebral palsy, but a lack of resources in rural and underprivileged areas remains a serious concern. Additionally, multi-organ failure in asphyxiated neonates, such as renal and cardiovascular problems, raises the risk of long-term morbidity(14).

Risk factors for perinatal asphyxia include maternal anemia, protracted labor, and meconium-stained amniotic fluid. Indian research found that prolonged labor and maternal anemia were important contributors to birth asphyxia in their studied population. Similarly, low birth weight and preterm were substantially linked to poor outcomes in asphyxiated neonates.

The mode of delivery also plays a critical role in the risk of birth asphyxia. Studies have shown that breech deliveries and instrumental deliveries are associated with a higher incidence of asphyxia and subsequent morbidity reported that breech deliveries were associated with a higher risk of neonatal mortality and morbidity due to asphyxia(14).

Globally, the pattern of birth asphyxia and its consequences have been thoroughly researched. Improvements in obstetric treatment have lowered the frequency of birth asphyxia in affluent countries, but the burden is still substantial in underdeveloped countries such as India. Similarly, term newborns with hypoxia in Kuwait showed a significant rate of neurological sequelae, underlining the global scope of the disease.

These findings highlight the critical need for improved prenatal care, early diagnosis, and accessible rehabilitation programs in India to lower the prevalence of cerebral palsy and other neurodevelopmental disabilities(14).

Hypoxic-Ischemic Encephalopathy (HIE) as a Precursor to Cerebral Palsy

Hypoxic-ischemic Encephalopathy (HIE) is an important intermediate disease between birth hypoxia and cerebral palsy. Lack of oxygen and blood supply to the brain causes neuronal damage and cell death. children with moderate to severe HIE have the highest risk of having CP, with studies indicating that 50-60% of these children acquire long-term neurological abnormalities such as movement impairments, cognitive delays, or seizures. HIE is classified into three stages based on clinical severity, with Stage II and III (moderate to severe HIE) being strongly associated with poor neurodevelopmental outcomes, including CP(15).

The pathophysiology of HIE involves a cascade of events, including energy failure, excitotoxicity, oxidative stress, and inflammation, which collectively contribute to brain injury. Infants with HIE often exhibit clinical signs of encephalopathy, such as hypotonia, seizures, and abnormal reflexes, within the first few hours to days of life. These signs are critical for early diagnosis and intervention(15).

Early identification of HIE is crucial for timely intervention and improved outcomes. Studies have shown that therapeutic hypothermia, initiated within 6 hours of birth, can significantly reduce the risk of severe neurological deficits and CP in infants with moderate to severe HIE. However, in resource-limited settings like India, access to advanced neonatal care, including therapeutic hypothermia, remains limited, leading to higher rates of adverse outcomes(15).

HIE risk factors include protracted labor, maternal anemia, and meconium-stained amniotic fluid, all of which are common in underdeveloped nations. Prolonged labor and maternal anemia have been identified as major factors of HIE in research populations. Similarly, low birth weight and preterm are closely linked to poor outcomes in newborns with HIE.

The global burden of HIE and its sequelae, including CP, is still significant, especially in low- and middle-income nations. Improvements in obstetric care have lowered the frequency of HIE in industrialized countries, but the burden is still disproportionately high in underdeveloped countries like India. These findings highlight the critical need for enhanced perinatal care, early detection, and readily available treatment interventions to lessen the burden of HIE and its long-term effects, including CP(16).

Screening Tools for Cerebral Palsy

Several screening tools are available for early detection of cerebral palsy, including:

- **Prechtl's General Movements Assessment (GMA**): A non-invasive tool for evaluating the quality of spontaneous movements in babies. Abnormal GM patterns, such as cramped-synchronized motions, are significant predictors of CP(17).
- **Hammersmith Infant Neurological Examination (HINE):** A standardized neurological assessment for infants(16).
- **MRI and Neuroimaging:** Advanced imaging techniques are used in developed countries but are often inaccessible in resource-limited settings like India.

In India, Prechtl's GMA is gaining recognition due to its cost-effectiveness and applicability in secondary care settings. However, its widespread adoption is limited by a lack of trained professionals(16).

Morbidities Associated with Delayed Diagnosis of Cerebral Palsy

Delayed diagnosis of CP leads to missed opportunities for early intervention, resulting in severe motor and cognitive impairments. Children with undiagnosed CP often experience(16):[16]

- **Motor Disabilities:** Spasticity, dystonia, and contractures.
- **Cognitive and Behavioral Issues:** Learning disabilities, attention deficits, and emotional disturbances.
- **Secondary Complications:** Epilepsy, speech and language delays, and feeding difficulties.

Early diagnosis through tools like Prechtl's GMA can significantly reduce these morbidities by enabling timely therapeutic interventions(16).

Prechtl's General Movements Assessment (GMA)

History of General Movements (GM):

General Movements (GM) are spontaneous movements that newborns exhibit between the ages of birth and five months. Heinz Prechtl pioneered the evaluation of GM in the 1980s, establishing its predictive significance for neurodevelopmental outcomes(7).

GM assessment is based on the quality of movements, with normal GM indicating a healthy nervous system and abnormal GM (e.g., cramped-synchronized movements) strongly predicting cerebral palsy (9).

Publications on GM in Preterm and Term Infants:

- Studies have shown that GM assessment is highly accurate in predicting CP in both preterm and term infants(18).
- According to the National Neonatology Forum (2003), preterm newborns with aberrant GM patterns are more likely to experience neurodevelopmental problems.
- In term infants with birth asphyxia, GM assessment can identify those at risk of HIE and CP(18).

GM in Birth Asphyxia:

- Infants with perinatal asphyxia often exhibit abnormal GM patterns, such as reduced complexity and variability(16).
- Prechtl's GMA is a good predictor of neurodevelopmental outcomes in resource-limited settings without modern diagnostic tools (National Neonatology Forum, 2003).

Morbidities of Cerebral Palsy (CP) Due to Delayed Diagnosis

Delayed diagnosis of cerebral palsy (CP) significantly exacerbates morbidity in children who survive birth asphyxia. Studies from India report that 10-20% of children with Hypoxic-Ischemic Encephalopathy (HIE) develop CP, with symptoms

typically appearing within the first two years of life(18) Delayed diagnosis often leads to missed opportunities for early intervention, resulting in lifelong disabilities such as motor impairments, cognitive deficits, and epilepsy(8) For instance, Shankaran et al. (1991)(4) found that infants with severe HIE had a 50-60% risk of developing CP, with many also experiencing intellectual disabilities and seizures.

In India, the burden of CP is exacerbated by restricted access to early diagnostic tools and rehabilitation programs. The National Neonatology Forum (2003) found that early identification and intervention can considerably improve outcomes for children with cerebral palsy, but a lack of resources in rural and underserved areas remains a serious concern.

Additionally, multi-organ dysfunction in asphyxiated neonates, such as renal and cardiovascular complications, further increases the risk of long-term morbidity (Jayashree et al., 1991; Mohan & Pai, 2000)(18).

Risk factors for CP include prolonged labor, maternal anemia, and meconium-stained amniotic fluid, which are prevalent in developing countries reported that prolonged labor and maternal anemia were significant contributors to birth asphyxia in their study population. Similarly, researchers discovered that low birth weight and prematurity were substantially associated with poor outcomes in asphyxiated infants(19).

The literature highlights the high prevalence of perinatal asphyxia and HIE in India, with significant long-term morbidities such as cerebral palsy. Prechtl's General Movements Assessment (GMA) emerges as a promising, non-invasive tool for early detection of neurodevelopmental impairments, particularly in resource-limited

settingsAdditional research and training in GM assessment are required to improve outcomes for newborns with birth asphyxia in India(20).

Burden of Perinatal Asphyxia and Its Consequences

Perinatal hypoxia is a prominent cause of infant mortality and morbidity worldwide, especially in underdeveloped countries such as India. According to the World Health Organization (WHO), birth asphyxia is responsible for 38% of under-five infant mortality worldwide, with a disproportionate impact in low- and middle-income nations. Perinatal asphyxia occurs in India at a rate of 5.9 to 9.1 per 1000 live births, with greater incidence in rural and neglected areas(19).

Infants who survive birth hypoxia frequently experience long-term neurodevelopmental abnormalities, with cerebral palsy (CP) being one of the most severe. According to Indian studies, 10-20% of children with Hypoxic-Ischemic Encephalopathy (HIE) develop cerebral palsy, with symptoms often showing during the first two years of life. Delayed diagnosis and inadequate early treatments aggravate morbidity, resulting in lifelong disabilities such as motor impairments, cognitive deficits, and epilepsy (Agrawal et al., 2012)(14).

Challenges in Early Diagnosis of Neurodevelopmental Impairments

Early detection of newborns at risk of neurodevelopmental abnormalities, such as cerebral palsy, is critical for prompt intervention and improved outcomes. However, traditional diagnostic tools, such as MRI and neuroimaging, are often inaccessible in resource-limited settings like India (National Neonatology Forum, 2003). Even in tertiary care centers, advanced imaging techniques may not be readily

available, making it difficult to predict outcomes in infants with perinatal asphyxia(21)

This gap in early diagnosis highlights the need for non-invasive, cost-effective tools that can be used in secondary and primary care settings. Prechtl's General Movements Assessment (GMA) has emerged as a promising tool in this regard, offering a reliable method for predicting neurodevelopmental outcomes in high-risk infants(22).

General Movements Assessment (GMA): History and Development

General Movements (GM) are spontaneous movements recorded in infants from birth to 5 months of age. Heinz Prechtl pioneered the assessment of GM in the 1980s, demonstrating its predictive value for neurodevelopmental outcomes (Sarnat&Sarnat, 1976)(7). GM assessment is based on the quality of movements, with normal GM indicating a healthy nervous system and abnormal GM (e.g., cramped-synchronized movements) strongly predicting cerebral palsy(21).

The assessment is non-invasive, cost-effective, and can be performed in various clinical settings, making it particularly useful in resource-limited environments (National Neonatology Forum, 2003). Unlike advanced imaging techniques, GMA does not require specialized equipment or extensive training, making it accessible to healthcare providers in secondary and primary care settings(4).

GMA in Preterm and Term Infants with Birth Asphyxia

According to research, GM evaluation is a highly accurate predictor of CP in both preterm and term newborns. Abnormal GM patterns in preterm newborns have been linked to an increased risk of neurodevelopmental deficits (National Neonatal

Forum, 2003). In term newborns with birth asphyxia, GM screening can identify individuals at risk of HIE and CP, allowing for early intervention and better results(22).

For example, [18] highlighted that infants with moderate to severe HIE often exhibit abnormal GM patterns, such as reduced complexity and variability, which are strong predictors of CP. Similarly found that infants with severe HIE and abnormal GM patterns had a 50-60% risk of developing CP, emphasizing the importance of early identification(10).

GMA in the Indian Context

In India, where access to advanced diagnostic equipment is limited, GMA provides a practical alternative for early detection of newborns at risk of neurodevelopmental abnormalities. Studies conducted in Indian neonatal care settings have supported the use of GMA in predicting outcomes in children with perinatal asphyxia (Jayashree et al., 1991; Mohan & Pai, 2000)(16,18). For example, found that GMA was extremely effective in detecting newborns at risk of CP in a tertiary care hospital in India.

However, widespread adoption of GMA in India is hampered by a shortage of qualified specialists and healthcare providers' understanding (National Neonatology Forum, 2003). Addressing these problems through training programs and awareness campaigns has the potential to greatly improve outcomes for newborns with perinatal asphyxia in India(23).

Why GMA is Preferred over Other Tools

Unlike advanced imaging techniques, GMA is non-invasive, cost-effective, and easy to perform, making it ideal for resource-limited settings(7). It does not require specialized equipment or extensive training, and can be performed using a simple video recording of the infant's movements (National Neonatology Forum, 2003). Additionally, GMA has been validated in numerous studies as a reliable predictor of neurodevelopmental outcomes, particularly CP(23)

The prevalence of prenatal hypoxia and its long-term repercussions, such as CP, highlight the critical need for early detection and care. Prechtl's General Movements Assessment (GMA) is a feasible, non-invasive, and cost-effective strategy for predicting neurodevelopmental outcomes in high-risk newborns, especially in resource-constrained environments such as India. By incorporating GMA into neonatal care procedures, healthcare providers can improve outcomes for infants with perinatal asphyxia and minimize the burden of lifelong impairments(23).

Incidence of Multiorgan Dysfunction in Perinatal Asphyxia

In a past study, researchers investigated the prevalence and impact of multiorgan dysfunction in neonates with perinatal asphyxia. The study found that 80.8% of asphyxiated babies exhibited multiorgan dysfunction, with respiratory failure being the most common (63.1%), followed by cardiovascular (54.3%) and renal involvement (29.8%). Mortality was significantly higher in babies with cardiovascular and renal dysfunction, increasing proportionally with the number of affected organs. The authors concluded that multiorgan dysfunction is a critical factor in perinatal asphyxia outcomes, emphasizing the need for early detection and management to improve survival rates. This study provides valuable insights into the

systemic effects of perinatal asphyxia, particularly highlighting the poor prognosis associated with cardiovascular and renal involvement(23).

Our findings revealed that a structured newborn physical therapy (SNP) program significantly improved neurobehavior and general movements (GMs) in moderate to late preterm (MLP) infants. The randomized controlled experiment included 60 MLP infants, 30 of whom received SNP (90 minutes per day, six days per week) in addition to standard care, and 30 who received only usual care. Assessments with the Neurobehavioral Assessment of Preterm Infant (NAPI) and Prechtl General Movements Assessment revealed significant gains in the SNP group, particularly in the NAPI scarf sign, motor development, and vigor clusters, as well as a reduction in poor repertoire GMs. The findings concluded that SNP enhances neurobehavioral(23) organization and GM quality in MLP infants, suggesting its potential to support early developmental outcomes in this population. This study adds valuable evidence supporting the integration of structured physical therapy into neonatal care for preterm infants in India.

In their 2023 paper, researchers stressed the significance of early diagnosis and treatments for cerebral palsy (CP) in high-risk newborn follow-up programs. They stated that cerebral palsy, the most common physical disability worldwide, affects about 10,000 infants in the United States each year and 400,000 internationally. While the frequency of severe CP has decreased due to breakthroughs in prenatal and postnatal care, lesser types of CP are becoming more common, making early detection difficult yet critical. Early detection enables early, targeted therapies, which are most successful in the first two to three years of life due to increased neuroplasticity(9). Early diagnosis also benefits parents since it allows for more honest communication, easier access to help, and better coping strategies. The

authors urged for the use of worldwide criteria for early CP detection, which include tests like the General Movements Assessment (GMA) and the Hammersmith Infant Neurological Examination (HINE), as well as neuroimaging and clinical history. They concluded that early diagnosis and intervention are critical to improving long-term outcomes for high-risk newborns and their families(24).

Researchers studied the stability of the Motor Optimality Score-Revised (MOS-R) in medically complicated newborns. The MOS-R is a clinical test used to examine spontaneous movements in infants aged 3-5 months and is linked to neurodevelopmental outcomes. This prospective cohort study included 85 infants who had previously been admitted to a neonatal intensive care unit (NICU). Infants were examined twice, once at 12-13 weeks corrected age (CA) and again at 14-16 weeks CA. The study sought to examine the consistency of MOS-R scores across different developmental timepoints, as well as to compare differences in stability across infants with higher and lesser medical complexity(24).

The MOS-R scoring system analyzes the spontaneous movement patterns (General Movements) of infants, assessing whether their neurological development is typical or if there is a likelihood of abnormalities, such as cerebral palsy. The data demonstrated that MOS-R scores were relatively stable across the two timepoints, with low bias (0.058) and strong agreement (95% confidence interval: -1.10, 1.22). However, when applying a MOS-R cut point of 19, children with higher medical complexity were more likely to switch groups between evaluations than those with lower complexity ($p = 0.008$). When cut points of 20 or 21 were used, no significant difference was seen. The study revealed that, while MOS-R scores are generally stable in NICU-hospitalized newborns, those with more medical complexity may be less stable at specific score levels. These findings emphasize the need to consider

medical complexity when evaluating MOS-R outcomes in clinical and follow-up settings(24).

The Motor Optimality Score-Revised (MOS-R) has been tested for predictive validity in newborns with congenital abnormalities that necessitate extensive neonatal surgery. A retrospective cohort study of 201 infants (mean gestational age: 38.2 weeks) discovered that MOS-R scores derived from General Movements Assessment (GMA) videos at 12-14 weeks post-term age were significantly associated with neurodevelopmental outcomes at 3 years, as measured by the Bayley Scales of Infant and Toddler Development. A MOS-R cut-off score of <21 is the strongest predictor of developmental delay or cerebral palsy (CP), with a sensitivity of 0.39 and specificity of 0.86. The study indicated that the MOS-R is an effective tool for identifying infants at risk of bad outcomes, especially when combined with other measures(24).

The quality of general movements (GMs) in term newborns with perinatal hypoxia has also been researched. A study of 64 term newborns discovered that abnormal GMs at the "writhing" age (38-47 weeks postmenstrual age) were associated with asphyxia-related disease, whereas faulty GMs at the "fidgety" age (48-56 weeks postmenstrual age) connected with abnormalities on neonatal brain ultrasound scans. The study identified GM evaluation as a valuable non-invasive method for early detection of infants at risk for developmental abnormalities(1).

A scoping review examined the effectiveness of the General Movements Assessment (GMA) in predicting CP in term and late-preterm children with neonatal encephalopathy. The review discovered that aberrant GMA at 3-5 months post-term had good specificity (84.6-98%) and negative predictive value (84.6-98%) for CP. Absent fidgety motions were extremely specific for moderate to severe CP, whereas

constricted coordinated movements were completely sensitive. The authors concluded that GMA is a cost-effective method for early CP identification(11).

Movement Imitation Therapy for Preterm Babies (MIT-PB), a new technique, has been introduced to improve neurodevelopmental outcomes in high-risk preterm newborns. A case study of four extremely preterm newborns with high-grade intraventricular hemorrhage (IVH) with cramped-synchronized GMs found that MIT-PB improved their GM patterns. By preschool age, all infants had normal neurodevelopmental outcomes, pointing to MIT-PB as a viable intervention for newborns at risk of CP(19).

A General Movement (GM) checklist was developed to assist novices in performing GMA. The checklist, validated using videos of 16 infants, showed high reliability in distinguishing normal from abnormal GM patterns. The authors concluded that the checklist is a reliable tool for early detection of neurodevelopmental disorders such as CP(19).

Quality of General Movements in Term Infants with Asphyxia

A 2008 study studied the quality of general movements (GMs) in term infants with perinatal hypoxia, with the goal of determining the association between perinatal risk factors and GM quality during the neonatal period and at three months of age. The study examined 64 term newborns (≥36 weeks postmenstrual age) with perinatal asphyxia. GMs were evaluated at two stages: "writhing" (38-47 weeks postmenstrual age) and "fidgety" (48-56 weeks postmenstrual age). Prenatal and perinatal factors were extensively gathered and studied(4).

Multivariate study found that aberrant GMs at the "writhing" age were predominantly associated with asphyxia-related disease. Abnormal GMs at the "fidgety" age were found to be substantially linked with abnormalities on neonatal brain ultrasonography images. The study indicated that GM assessment, particularly at 3 months of age, is a useful, non-invasive method for assessing nervous system integrity in term infants with hypoxia. This approach provides the early detection of newborns at risk for developmental problems, allowing for timely intervention(5).

A 2021 scoping analysis examined the effectiveness of the General Movements Assessment (GMA) in predicting cerebral palsy (CP) in term and late-preterm infants with neonatal encephalopathy. The evaluation sought to summarize available knowledge and identify research gaps. Five databases and the General Movements Trust website were examined, yielding three studies (one cohort and two case series) containing 118 persons who met the inclusion criteria. Notably, no studies examined late-preterm newborns(25).

The study discovered that an aberrant GMA at 3-5 months post-term had good specificity (84.6-98%) and negative predictive value (84.6-98%) for CP. Absent fidgety movements, in particular, were highly specific (96%) for moderate to severe CP and had a strong negative predictive value (98%) when normal. Cramped synchronous motions observed throughout term and 4-5 months after term demonstrated 100% sensitivity but varying specificity and predictive values. The authors concluded that in high-risk term newborns, a normal GMA at 3 months is associated with a low probability of moderate/severe CP. The presence of tight, coordinated movements is a major predictor of CP, highlighting the GMA's utility as a non-invasive, cost-effective method for early CP detection and intervention(25).

A 2019 case study described Movement Imitation Therapy for Preterm Babies (MIT-PB), a novel early intervention strategy aimed at improving neurodevelopmental outcomes in high-risk preterm newborns. The study included four extremely preterm newborns diagnosed with high-grade intraventricular hemorrhage (IVH) with cramped-synchronized (CS) general movements (GMs) at 33-35 weeks postmenstrual age. MIT-PB involved therapists gently directing the infants' limbs to resemble typical GM sequences when CS movements were detected. This therapy was given for at least 10 minutes, five times a day, for 10-12 weeks(25).

The findings showed that GM patterns improved, with three newborns exhibiting normal fidgety movements by 14 weeks post-term, and one infant exhibiting abnormal fidgety motions. By preschool age, all four infants had normal neurodevelopmental results. The authors concluded that MIT-PB, which replicates normal GM sequences, may improve neurodevelopment in high-risk neonates. However, they stressed the importance of additional replication studies with bigger sample sizes to corroborate these findings. This method provides a promising advancement in intervention efforts for newborns with cerebral palsy(25) .

A 2020 study developed and validated a General Movement (GM) checklist to assist novices in performing General Movement Assessment (GMA)(14). The checklist aimed to quantify GMA and differentiate between normal and abnormal GM patterns. The study involved three examiners who assessed 20 videos of 16 infants (7 males) recorded during the writhing GM period (31–45 weeks postmenstrual age). The checklist scored GM features on a scale of 0 to 26, with higher scores indicating normal GMs(19).

The results showed that the checklist was well-received by the participants. Normal GMs had a substantially higher median checklist score (26) compared to aberrant GMs (11) ($p < 0.001$). The checklist also effectively distinguished between poor-repertoire (median = 13) and cramped-synchronized GMs (median = 7, $p < 0.002$). Inter- and intra-scorer agreement was good to exceptional for identifying normal versus aberrant GMs (Kappa = 0.68-1.00), GM categories (Kappa = 0.56-0.93), and checklist scores (ICC = 0.77-0.96). The authors concluded that the GM checklist is a reliable tool for quantifying GMA and discriminating between normal and abnormal GM patterns, making it an important resource for the early detection of neurodevelopmental diseases like cerebral palsy(26).

The prevalence of prenatal hypoxia and its long-term repercussions, such as CP, highlight the critical need for early detection and care in India. Prechtl's General Movements Assessment (GMA) is a feasible, non-invasive, and cost-effective tool for predicting neurodevelopmental outcomes in high-risk newborns, especially in resource-limited settings. By integrating GMA into neonatal care protocols, healthcare providers can improve outcomes for infants with perinatal asphyxia and reduce the burden of lifelong disabilities(27).

Indian studies have made substantial contributions to our understanding of the function of General Movements Assessment (GMA) in predicting neurodevelopmental outcomes, particularly in high-risk infants. For example, Khurana et al. (2021)(28) conducted a randomized controlled trial (RCT) in India and found that a structured neonatal physical therapy (SNP) program enhanced neurobehavioral organization and overall movement quality in moderate to late preterm (MLP) newborns. The study found that adding SNP to normal care lowered the proportion of newborns with poor-repertoire GMs while improving motor

development and vigor clusters on the Neurobehavioral Assessment of Preterm newborns (NAPI) (Khurana et al., 2021)(28).

A 2023 study on birth asphyxia in Indian neonates highlighted the significance of monitoring renal parameters and serum calcium levels. While this study did not directly employ General Movements Assessment (GMA), it emphasized the systemic effects of perinatal asphyxia, reinforcing the need for early detection tools like GMA to identify infants at risk of cerebral palsy (CP) and other neurodevelopmental disorders. These findings align with broader efforts to integrate GMA into Indian neonatal care for timely diagnosis and intervention(29).

Other studies have extensively investigated the predictive validity and clinical value of GMA in high-risk neonates. A 2008 Dutch study demonstrated that General Movements Assessment (GMA), particularly during the fidgety movement stage (3 months post-term), is an effective tool for evaluating neurological integrity in term infants with perinatal hypoxia. The study found that aberrant GMs at this stage strongly correlated with abnormalities on neonatal brain ultrasound scans, underscoring GMA's role in early identification of infants at risk for developmental impairments(28). Similarly, a 2023 Australian study investigated the Motor Optimality Score-Revised (MOS-R) in newborns with congenital abnormalities requiring neonatal surgery. Results indicated that a MOS-R score below 21 predicted unfavorable neurodevelopmental outcomes, including cerebral palsy (CP), with high specificity (86%) and moderate sensitivity (39%)(19).

Further research in 2019 introduced Movement Imitation Therapy for Preterm Babies (MIT-PB), an intervention designed for infants with high-grade intraventricular hemorrhage (IVH) and cramped-synchronized (CS) GMs. The

therapy, which involved mimicking typical GM patterns, showed promising outcomes, with three of four infants achieving normal fidgety movements by 14 weeks post-term age and normal neurodevelopment at preschool follow-up. Additionally, a 2020 Brazilian study developed a simplified GM checklist to improve GMA accessibility for novice assessors. The tool demonstrated high reliability in distinguishing normal from abnormal GMs, with excellent inter- and intra-rater agreement, supporting its utility in early detection of neurodevelopmental disorders(29).

Global Consensus and Future Directions

The global consensus, as highlighted by Maitre et al. (2023), is that early detection and intervention for CP using tools like GMA are essential for optimizing long-term outcomes in high-risk infants. The application of worldwide standards for early CP identification, including the use of GMA and MOS-R, has been demonstrated to be practicable and successful in a variety of healthcare settings (Maitre et al., 2023)(30). Seesahai et al. (2021) supported this with a scoping review, which discovered that atypical GMs, notably the absence of fidgety movements, are highly specific (96%) for moderate to severe CP, with a strong negative predictive value (98%) when normal(31). These findings highlight the necessity of including GMA into standard newborn follow-up programs around the world in order to promote early diagnosis and timely intervention(29).

In conclusion, both Indian and international studies highlight the critical role of GMA in early detection of neurodevelopmental disorders, particularly CP. While Indian Studies are increasingly adopting GMA in clinical practice, global research continues to refine its application and explore innovative interventions like MIT-PB.

The collective evidence supports the widespread implementation of GMA as a cost-effective, non-invasive tool for improving outcomes in high-risk infants(28).

Conclusion

Perinatal asphyxia is still a major public health concern in India, with an incidence of 2 to 10 per 1000 term deliveries and significantly higher rates in preterm infants (National Neonatology Forum, 2003). According to the World Health Organization (WHO), birth asphyxia causes 4 million newborn deaths each year, accounting for 38% of under-five child mortality worldwide (Black et al., 2010)(1). In India, risk factors for neonatal asphyxia include maternal anemia, protracted labor, meconium-stained amniotic fluid, and low birth weight (Bhargava et al., 1988; Singh et al., 1992)(32). These conditions contribute to the high prevalence of hypoxic-ischemic encephalopathy (HIE), a neurological complication of prenatal asphyxia that affects 20-30% of asphyxiated neonates in India (Agrawal et al., 2012)(21).

Children who survive birth hypoxia frequently experience long-term neurodevelopmental problems, with cerebral palsy (CP) being one of the most severe. According to studies from India, 10-20% of children with HIE develop CP, with symptoms often emerging during the first two years of life (Jayashree et al., 1991; Mohan and Pai, 2000)(16,18). However, it is uncertain which newborns with perinatal hypoxia may acquire neurological deficits, as many children have atypical development (Sarnat & Sarant, 1976)(7). Delayed diagnosis and inadequate early treatments aggravate morbidity, resulting in lifelong disabilities such as motor impairments, cognitive deficits, and epilepsy (Agrawal et al., 2012)(21).

Birth asphyxia is defined by the Indian Academy of Pediatrics (IAP) as an umbilical cord blood pH of <7.0 or a base deficit of ≥12 mmol/L, accompanied with clinical indications of encephalopathy including hypotonia, seizures, or impaired reflexes (National Neonatology Forum, 2003). Despite advancements in neonatal care, predicting neurodevelopmental outcomes in infants with perinatal asphyxia remains difficult, especially in resource-constrained settings where advanced diagnostic tools such as MRI and magnetic resonance spectroscopy are unavailable (Hansen & Soul, 2012)(33).

In this context, Prechtl's General Movements Assessment (GMA) has emerged as a promising, non-invasive, and cost-effective tool for predicting neurodevelopmental outcomes in high-risk infants. GMA evaluates the quality of spontaneous movements in infants from birth to 5 months of age, with abnormal patterns such as cramped-synchronized movements strongly predicting CP (Sarnat & Sarnat, 1976)(7). Studies from Indian neonatal care settings have validated the use of GMA in identifying infants at risk of CP and other neurodevelopmental impairments (Agrawal et al., 2012). However, the widespread adoption of GMA in India is limited by a lack of trained professionals and awareness among healthcare providers (National Neonatology Forum, 2003).

In conclusion, perinatal asphyxia and its long-term consequences, such as CP, underscore the urgent need for early diagnosis and intervention in India. Prechtl's General Movements Assessment (GMA) offers a practical solution for predicting neurodevelopmental outcomes in high-risk infants, particularly in resource-limited settings. By integrating GMA into neonatal care protocols and addressing the challenges of training and awareness, healthcare providers can improve outcomes for infants with perinatal asphyxia and reduce the burden of lifelong disabilities(34).

Despite significant advancements in understanding perinatal asphyxia and its consequences, several research gaps remain, particularly in the context of India. These gaps highlight the need for further studies to improve early diagnosis, intervention, and long-term outcomes for infants affected by perinatal asphyxia. Below are the key research gaps identified:(34) Despite studies from India reporting a prevalence of 2 to 10 per 1000 term births, large-scale, population-based epidemiological data on perinatal asphyxia remain scarce, with most research limited to tertiary care centers that may not reflect the true burden in rural and underserved areas (National Neonatology Forum, 2003). Nationwide surveys are needed to assess prevalence, risk factors, and outcomes across diverse regions. While maternal anemia, prolonged labor, and meconium-stained amniotic fluid are recognized risk factors, region-specific influences—such as socioeconomic conditions, cultural practices, and healthcare access—are understudied (Bhargava et al., 1988; Singh et al., 1992)(32). Diagnostic challenges persist in resource-limited settings, where advanced tools like MRI are often unavailable (Hansen & Soul, 2012). Although Prechtl's General Movements Assessment (GMA) offers a low-cost alternative, its adoption is hindered by a lack of trained professionals and awareness (National Neonatology Forum, 2003). Further studies are required to evaluate GMA's feasibility in Indian contexts and to expand training programs for healthcare providers. Long-term neurodevelopmental outcomes, particularly beyond the first two years of life, are poorly documented, despite 10-20% of infants with hypoxic-ischemic encephalopathy (HIE) developing cerebral palsy (Jayashree et al., 1991; Mohan & Pai, 2000)(16,18). Early interventions like therapeutic hypothermia show promise but are inaccessible in many Indian settings, necessitating research into affordable alternatives and the long-term impact of rehabilitation (Hansen & Soul, 2012)(35). Additionally, while GMA has been validated in high-income countries, its accuracy and reliability in Indian

populations—especially across rural and urban disparities—require further validation (Agrawal et al., 2012)(14). The broader implementation of evidence-based practices is further hampered by insufficient training and awareness among healthcare providers (National Neonatology Forum, 2003). Addressing these gaps through large-scale epidemiological studies, region-specific risk analyses, validation of diagnostic tools, and capacity-building initiatives is critical to mitigating the burden of perinatal asphyxia and improving outcomes for affected infants in India(35).

Research Gaps Identified in General Movements Assessment (GMA) and Neurodevelopmental Outcomes

The reviews and studies on General Movements Assessment (GMA) and its role in predicting neurodevelopmental outcomes, particularly cerebral palsy (CP), have highlighted several research gaps that need to be addressed to enhance the clinical utility and global adoption of GMA. Below is a summary of the key research gaps identified:(36)

While GMA has been validated as a reliable tool, there is variability in its implementation across different healthcare settings. For example, the study by Aizawa et al. (2020)(36) developed a GM checklist to assist novices, but its widespread adoption and integration into clinical practice remain limited. Standardized protocols and training programs for GMA should be developed and tested across diverse healthcare settings, particularly in low- and middle-income countries (LMICs) where resources may be limited (Aizawa et al., 2020)(36).

Most GMA studies, including those by van Iersel et al. (2008)(37) and Crowle et al. (2023)(38), have been conducted in high-income countries or specific populations (e.g., infants with congenital anomalies or perinatal asphyxia). There is

limited data on the applicability of GMA in diverse cultural and socioeconomic contexts, particularly in LMICs. Research should explore the feasibility and effectiveness of GMA in diverse populations, including those with limited access to advanced neonatal care, to ensure its global applicability (van Iersel et al., 2008; Crowle et al., 2023)(38).

While GMA is a powerful standalone tool, its integration with other diagnostic methods, such as neuroimaging (e.g., MRI) or genetic testing, is not well explored. For example, van Iersel et al. (2008) found correlations between abnormal GMs and brain ultrasound findings, but the combined use of GMA with advanced imaging techniques remains understudied. Future studies should investigate the combined use of GMA with other diagnostic tools to enhance the accuracy of early CP prediction and identify subtypes of neurodevelopmental disorders (van Iersel et al., 2008)(37).

Problem Statement

Research Problem

The primary research problem is the lack of accessible and reliable tools for early prediction of neurodevelopmental outcomes in term neonates with perinatal asphyxia, particularly in resource-limited settings like India. While Prechtl's General Movements Assessment (GMA) offers a promising solution, there is a need for further research to validate its effectiveness in Indian populations and to address the challenges of training and awareness among healthcare providers.

Perinatal asphyxia is a significant cause of neonatal morbidity and mortality, particularly in developing countries like India. It affects 2 to 10 per 1000 term newborns and is responsible for 38% of under-five child deaths globally (Black et al.,

2010)(1). In India, the burden of perinatal asphyxia is exacerbated by factors such as maternal anemia, prolonged labor, meconium-stained amniotic fluid, and low birth weight, which are prevalent in rural and underserved areas (Bhargava et al., 1988; Singh et al., 1992)(32). Despite advancements in neonatal care, predicting neurodevelopmental outcomes in infants with perinatal asphyxia remains a major challenge, particularly in resource-limited settings where access to advanced diagnostic tools is limited(32).

Infants who survive perinatal asphyxia often face long-term neurodevelopmental impairments, with cerebral palsy (CP) being one of the most severe outcomes. Studies from India report that 10-20% of children with Hypoxic-Ischemic Encephalopathy (HIE) develop CP, with symptoms typically appearing within the first two years of life (Jayashree et al., 1991; Mohan & Pai, 2000)(16,18). However, it is still unclear which infants with perinatal asphyxia will develop neurological impairments, as many children exhibit atypical development (Sarnat&Sarnat, 1976)(7). Delayed diagnosis and lack of early intervention exacerbate the morbidity, leading to lifelong disabilities such as motor impairments, cognitive deficits, and epilepsy (Agrawal et al., 2012)(14).

Traditional diagnostic tools, such as MRI and magnetic resonance spectroscopy, are highly effective in predicting neurodevelopmental outcomes but are often inaccessible in secondary and primary care settings in India (Hansen & Soul, 2012)(35). This gap in early diagnosis highlights the need for non-invasive, cost-effective tools that can be used in resource-limited settings. Prechtl's General Movements Assessment (GMA) has emerged as a promising tool in this regard, offering a reliable method for predicting neurodevelopmental outcomes in high-risk infants. GMA evaluates the quality of spontaneous movements in infants from birth to

5 months of age, with abnormal patterns such as cramped-synchronized movements strongly predicting CP (Sarnat&Sarnat, 1976)(7).

However, there is a lack of large-scale studies validating the effectiveness of GMA in term neonates with perinatal asphyxia, particularly in Indian settings. While GMA has been validated in high-income countries, its accuracy and reliability in diverse Indian populations remain understudied (Agrawal et al., 2012)(14). Additionally, the adoption of GMA in India is hindered by a lack of trained professionals and awareness among healthcare providers (National Neonatology Forum, 2003). Addressing these challenges is critical to improving outcomes for infants with perinatal asphyxia in India(38).

MATERIALS AND METHODS

SOURCE OF DATA

Inborn or outborn neonates born between 37-42 weeks of gestation in KLES Dr. Prabhakar Kore Hospital, Belagavi and its satellite centres with the same followed up at 3 months of age were enrolled in this study.

STUDY DESIGN

The study design was longitudinal, as it involved follow-up assessments at two time points: at discharge and at 3 months of age.

STUDY PERIOD

One Year study period from July 2023- August 2024.

SAMPLE SIZE

$$n = \left[\frac{Z_{1-\alpha}*\sqrt{P_{disc}} + Z_{1-\beta}*\sqrt{P_{disc}-Q_{diff}^2}}{Q_{diff}}\right]^2$$

For $\alpha = 5\%$ $Z_{1-\alpha}$ = 1.96

β = 20% $Z_{1-\beta}$= 0.84

Substituting these values in the above equation we get n=59.17 ≈60

INCLUSION CRITERIA

- Inborn or outborn neonates born between 37-42 weeks of gestation (term gestation) requiring prolonged resuscitation or intubation with Cord Arterial Blood Gas showing showing a Ph <7 or a base deficit ≥ 12-16mmol/L i.e Proof of perinatal Asphyxia
- Informed consent obtained from parents/guardians.

EXCLUSION CRITERIA

- Neonates with significant congenital anomalies.
- Infants for whom parents/guardians did not provide consent.

INFORMED CONSENT

Parents of eligible neonates were briefed about the study's nature, and written informed consent was obtained. Consent forms were available in English and the region's major languages, including Kannada, Marathi, and Hindi (ANNEXURE 1).

STUDY PROTOCOL

1. Ethical clearance was obtained before the study began.

2. Neonates meeting the inclusion criteria were selected from KLES Dr. Prabhakar Kore Hospital, Belagavi and its satellite centres and Modified Sarnat staging was done.

3. Informed consent was obtained from parents/guardians after explaining the study's purpose and procedures.

4. Data was collected using an electronic device to record a 2-4 minute video of the baby at two time points:

- At discharge
- At 3 months of age

5. A semi-structured proforma was used to collect details about the baby, including antenatal and natal history. (ANNEXURE 2)

6. Neurodevelopmental outcomes were assessed using Prechtl's General Movements Assessment (GMA) and Motor Optimality Score-Revised (MOS-R). (ANNEXURE 2)

DATA COLLECTION PROCEDURE

1. The babies with diagnosed Perinatal Asphyxia were staging according to the modifies Sarnat and Sarnat Staging. After obtaining consent, a 2-4 minute video of the baby was recorded by the trained staff in the NICU or the Post-natal wards at discharge. The video was recorded when the baby is in an active, awake, playful state with no disturbance from the surroundings or distractions like playtoys and is moving by itself.

2. The same baby was reassessed at 3 months of age with another 2-4 minute video when followed up at our KLES Dr. Prabhakar Kore Hospitals High Risk Baby Clinic or by a video sent by the parents after providing clear instructions on the video recording to evaluate general movements and predict neurodevelopmental outcomes using MOS-R scoring.

ETHICAL CLEARANCE

The study received ethical approval from the JNMC Institutional Ethical Committee (Ref No: MDC/JNMCIEC/91) on March 26th , 2023.

C.T.R.I REGISTRATION

The study was registered with the Clinical Trial Registry of India (CTRI) before sample collection and received approval under the registration number CTRI/2023/06/054567

Observation and result analysis

STATISTICAL ANALYSIS

The data collected was coded, organized, and stored in a Microsoft Excel spreadsheet. Descriptive statistics were used to summarize the data, with mean and standard deviation calculated for quantitative variables, while categorical variables were presented as frequencies and proportions. Data visualization techniques included bar charts, graphs. To assess the relationship between explanatory variables and categorical outcomes, cross-tabulation and percentage comparisons were performed, with the chi square test used to determine statistical significance. Independent sample t-tests were applied to compare quantitative variables between two groups, whereas paired sample t-tests were used for within-group comparisons of paired quantitative data. A p-value of less than 0.05 was considered statistically significant. Statistical analysis was conducted using IBM SPSS Statistics for Windows, Version 22.0 (IBM Corp., Armonk, NY).

RESULTS

The study was conducted from July 2023 to August 2024 in the Neonatal Intensive Care Unit (NICU),High Risk baby Clinic, Post-Natal wards of the Department of Paediatrics at KLES Dr. Prabhakar Kore Hospital and Medical Research Centre and its satellite centres, affiliated with Jawaharlal Nehru Medical College, Belagavi. During the study period, a total 70 samples were eligible for the study after careful consideration of the inclusion and the exclusion criteria. Among these cases, three infants were discharged against medical advice and three deaths. Additionally, parental consent was not given for three cases, and one infant was lost to follow-up. Ultimately, 60 infants were successfully followed up until three months of age, and their data were included in the final analysis.

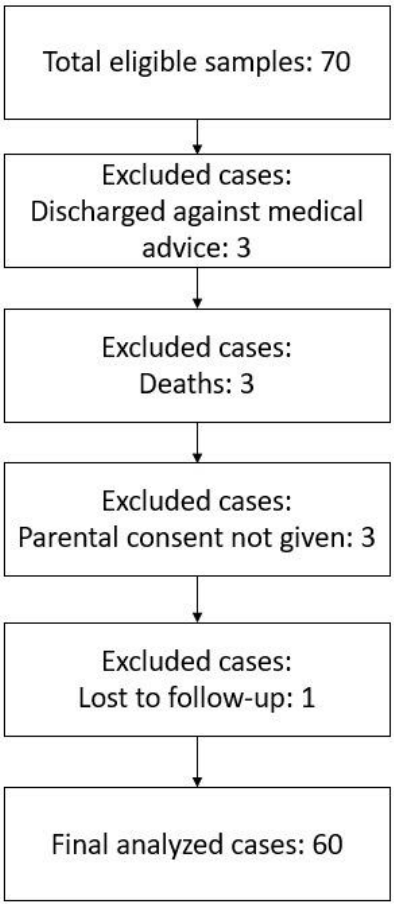


Table 1 Association between MOS-R and Gender

		MOS-R								Chi-square (p-value)
		Optimal		Mildly reduced		Moderately reduced		severely reduced		
		n	%	n	%	n	%	n	%	
Sex	Male	28	75.7	2	5.4	7	18.9	0	0.0	5.206 (0.122)
	Female	16	69.6	0	0.0	4	17.4	3	13.0	

Graph 1 Gender wise comparison of MOS-R scale

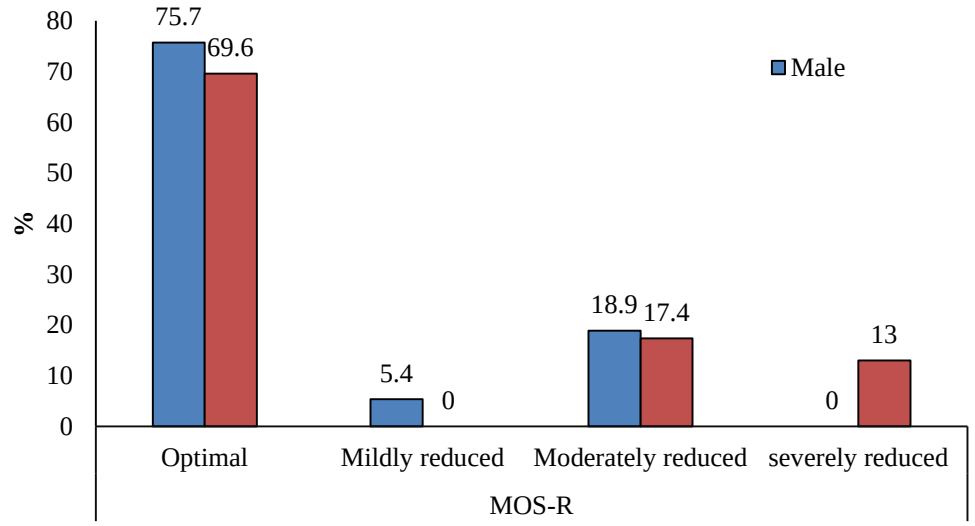


Table 1examines the distribution of MOS-R categories by sex. The results showed no statistically significant relationship between sex and MOS-R classification, with a chi-square value of 5.206 and a p-value of 0.122. Most males (75.7%) were in the "Optimal" group, whereas 5.4% were in the "Mildly reduced," 18.9% were in the "Moderately reduced," and none were in the "Severely reduced" category. On the other hand, 69.6% of females fell into the "Optimal" category, while 13.0% were categorised as "Severely reduced," 17.4% as "Moderately reduced," and no instances as "Mildly reduced.

Table 2 Association between MOS-R and Mode of Delivery

		MOS-R								Chi-square (p-value)
		Optimal		Mildly reduced		Moderately reduced		severely reduced		
		n	%	n	%	n	%	n	%	
Mode of Delivery	NVD	26	65.0	2	5.0	9	22.5	3	7.5	3.728 (0.242)
	LSCS	18	90.0	0	0.0	2	10.0	0	0.0	

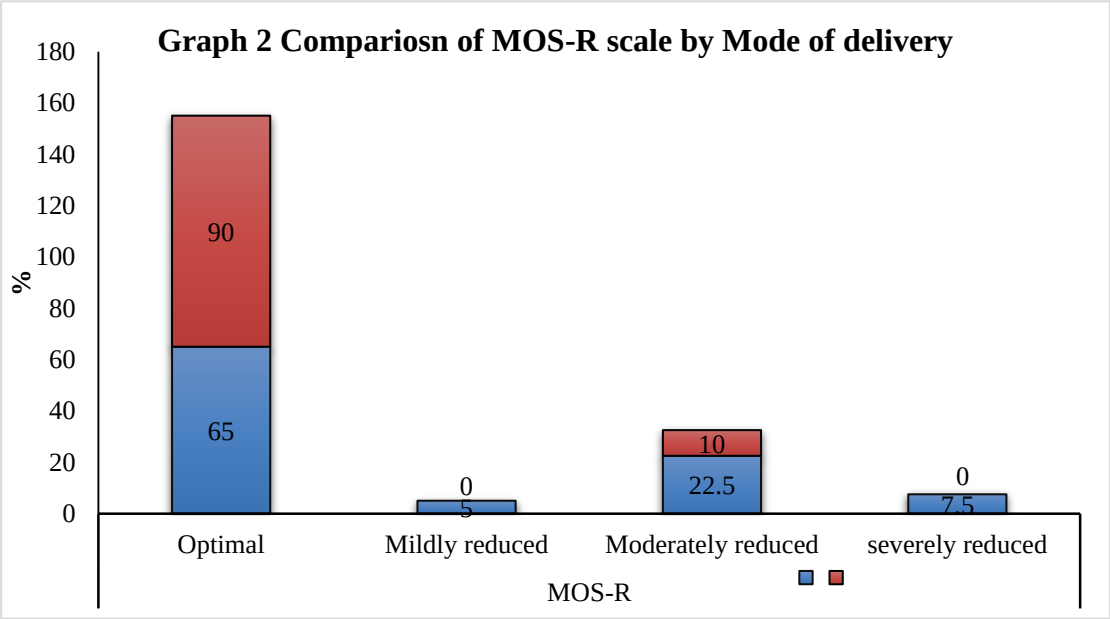


Table 2 A chi-square test was used to examine the distribution of MOS-R categories according to the Mode of delivery. The results showed no statistically significant association between the mode of delivery and MOS-R classification, with a chi-square value of 3.728 and a p-value of 0.242. Of those born via normal vaginal delivery (NVD), 65.0% were "Optimal," 5.0% to be "Mildly reduced," 22.5% to be "Moderately reduced," and 7.5% to be "Severely reduced." While there were no cases in the "Mildly reduced" or "Severely reduced" groups, 90.0% of those delivered via lower segment caesarean section (LSCS) fell into the "Optimal" category, and 10.0% were categorised as "Moderately reduced.

Table 3 Association between MOS-R and Maternal Hypertension

		MOS-R								Chi-square (p-value)
		Optimal		Mildly reduced		Moderately reduced		Severely reduced		
		n	%	n	%	n	%	n	%	
Maternal Hypertension	No	24	75.0	2	6.3	5	15.6	1	3.1	2.278 (0.627)
	Yes	20	71.5	0	0.0	6	21.4	2	7.1	

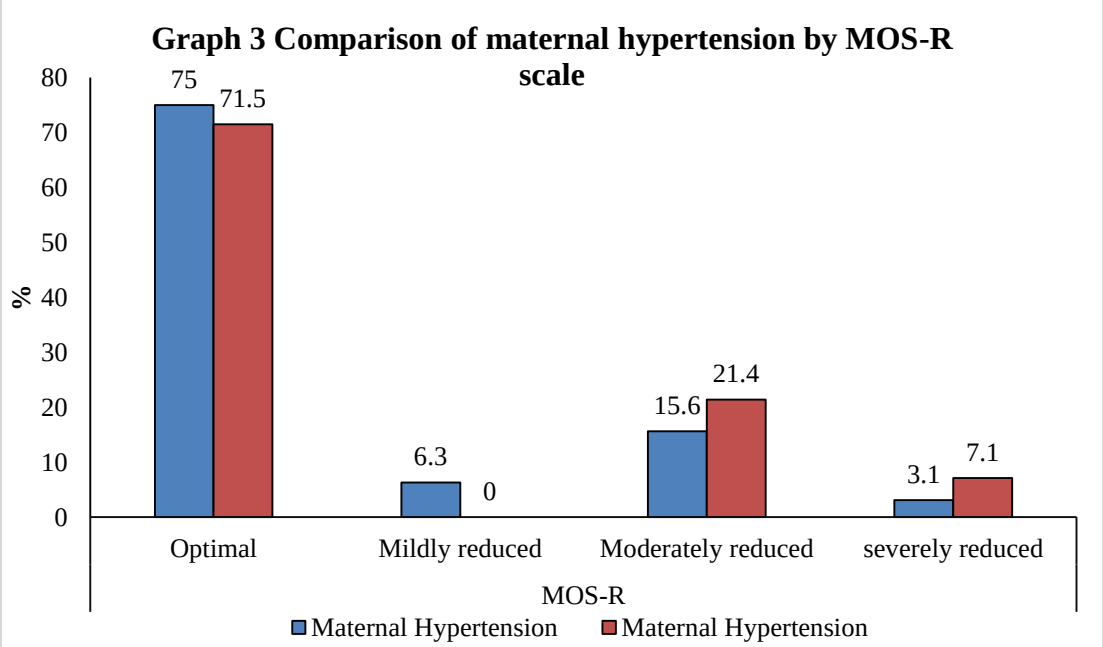


Table 3 A chi-square test was used to evaluate the relationship between maternal hypertension and MOS-R classification; the results showed no statistically significant relationship with a chi-square value of 2.278 and a p-value of 0.627. Of those without maternal hypertension, 75.0% were classified as "Optimal," 6.3% as "Mildly reduced," 15.6% as "Moderately reduced," and 3.1% as "Severely reduced." In contrast, 71.4% of those with maternal hypertension fell into the "Optimal" category, with no cases in the "Mildly reduced" group, 21.4% as "Moderately reduced," and 7.1% as "Severely reduced.

Table 4 Association between MOS-R and Anemia

		MOS-R								Chi-square (p-value)
		Optimal		Mildly reduced		Moderately reduced		Severely reduced		
		n	%	n	%	n	%	n	%	
Anaemia	No	26	72.3	0	0.0	7	19.4	3	8.3	4.217 (0.239)
	Yes	18	75.0	2	8.3	4	16.7	0	0.0	

Graph 4 Comparison of MOS-R scale by Anaemia

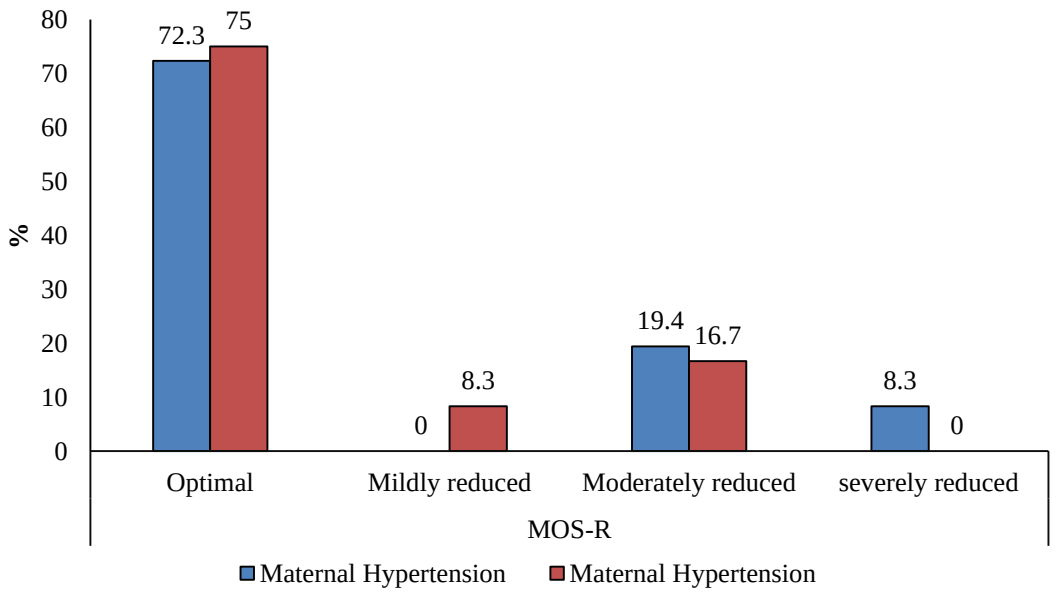


Table 4 A chi-square test was used to assess the relationship between anaemia and MOS-R classification; the results showed no statistically significant relationship, with 72.3% of those without anaemia falling into the "Optimal" category, none into the "Mildly reduced" category, 19.4% into the "Moderately reduced," and 8.3% into the "Severely reduced." In contrast, 75.0% of those with anaemia fell into the "Optimal" category, 8.3% into the "Mildly reduced," 16.7% into the "Moderately reduced," and none into the "Severely reduced.

Table 5 Association between MOS-R and Antenatal care

		MOS-R								Chi-square (p-value)
		Optimal		Mildly reduced		Moderately reduced		severely reduced		
		n	%	n	%	n	%	n	%	
Antenatal Care	Poor	7	70.0	0	0.0	2	20.0	1	10.0	1.486 (0.767)
	Good	37	74.0	2	4.0	9	18.0	2	4.0	

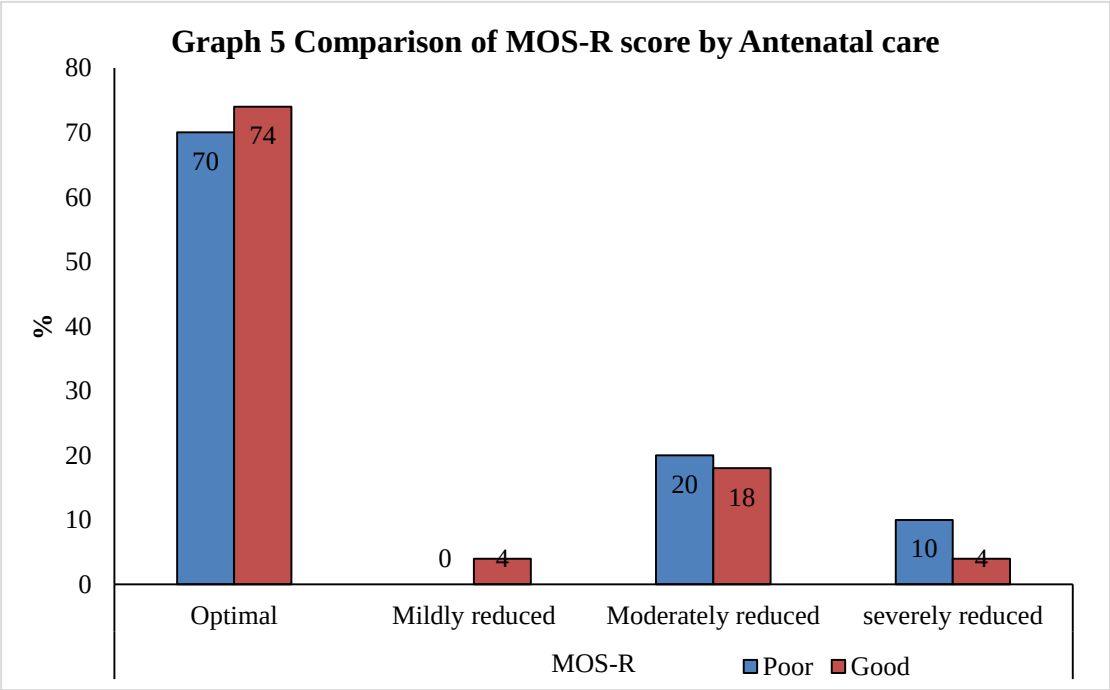


Table 5: The association between antenatal care quality and MOS-R classification was analyzed using a chi-square test, yielding a chi-square value of 1.486 with a p-value of 0.767, indicating no statistically significant relationship. Among those who received poor antenatal care, 70.0% were classified as "Optimal," none were in the "Mildly reduced" category, 20.0% were "Moderately reduced," and 10.0% were "Severely reduced." In comparison, among those who received good antenatal care, 74.0% were in the "Optimal" category, 4.0% were "Mildly reduced," 18.0% were "Moderately reduced," and 4.0% were "Severely reduced."

Table 6 Association between MOS-R and Obstructed labor/Prolonged labor

		MOS-R								Chi-square (p-value)
		Optimal		Mildly reduced		Moderately reduced		severely reduced		
		n	%	n	%	n	%	n	%	
Obstructed Labor/Prolonged labor	No	32	88.9	1	2.8	3	8.3	0	0.0	11.993 (0.002)*
	Yes	12	50.0	1	4.2	8	33.3	3	12.5	

Table 6 evaluate the association between obstructed/prolonged labor and MOS-R classification; the results showed a statistically significant relationship, with a chi-square value of 11.993 and a p-value of 0.002. Eighty-nine percent of those without prolonged or obstructed labor were categorised as "Optimal," 2.8% as "Mildly reduced," 8.3% as "Moderately reduced," and none as "Severely reduced." However, only 50.0% of those who had obstructed or prolongedlabour were categorised as "Optimal," compared to 4.2% who were "Mildly reduced," 33.3% who were "Moderately reduced," and 12.5% who were "Severely reduced." This strong association raises the possibility that prolonged or obstructed labour might have a detrimental effect on MSO-R results.

Graph 6 Comparison of MOS-R scale by Obstructed/ Prolonged labor

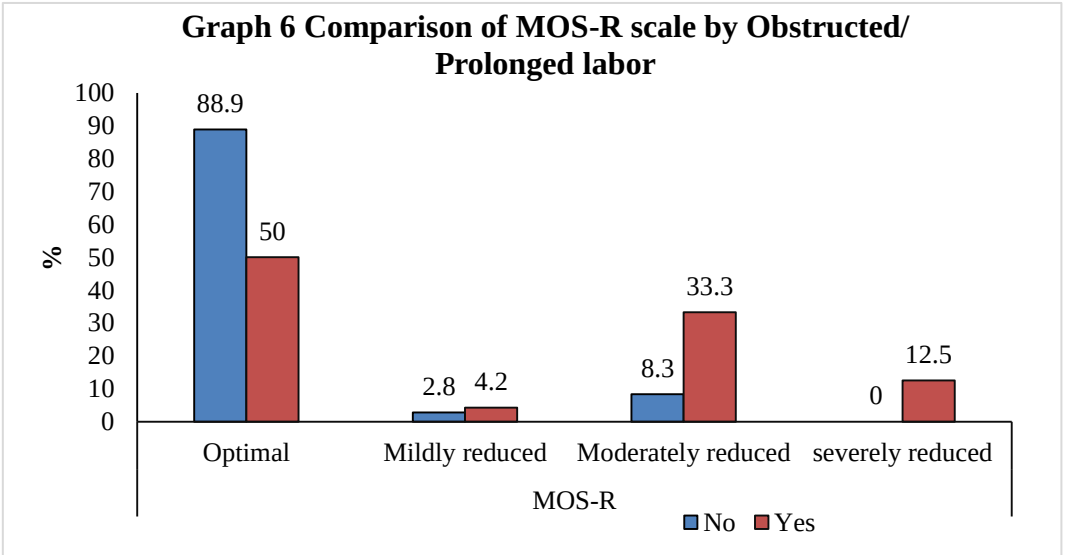


Table 7 Association between MSO-R and Neonatal Resuscitation

		MOS-R								Chi-square (p-value)
		Optimal		Mildly reduced		Moderately reduced		severely reduced		
		n	%	n	%	n	%	n	%	
Neonatal Resuscitation	No Cry-Intubated	0	0.0	0	0.0	9	81.8	2	18.2	42.090 (<0.05)*
	Cried after Bag and Mask	17	94.4	0	0.0	1	5.6	0	0.0	
	Cried after prolonged Bag and Mask	11	73.3	2	13.3	1	6.7	1	6.7	
	Cried after Stimulation	16	100.0	0	0.0	0	0.0	0	0.0	

Graph 7 Comparison of Neonatal resuscitation by MOS-R scale

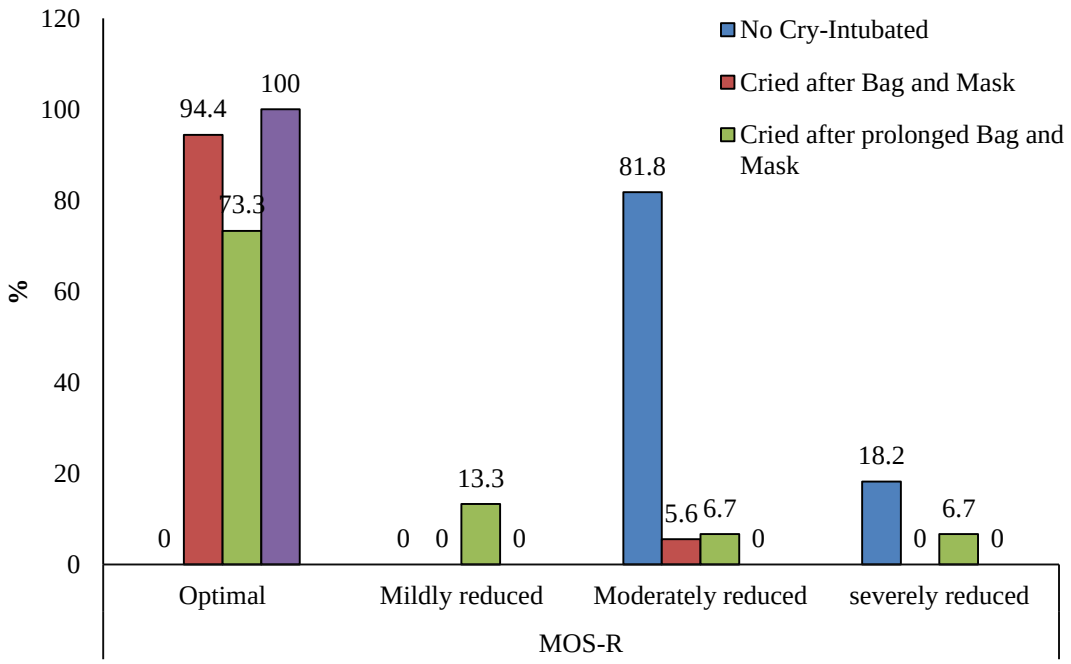


Table 7 Shows Neonatal resuscitation and MOS-R classification were significantly associated, according to the chi-square test ($\chi^2 = 42.090$, $p < 0.05$). 81.8% of neonates who needed intubation were categorised as "Moderately reduced," and 18.2% as "Severely reduced." There were no cases in the "Optimal" or "Mildly reduced" categories. The "Optimal" group included 94.4% of those who sobbed following bag and mask ventilation. In a similar vein, 73.3% of those who sobbed after wearing a bag and mask for a long time were "Optimal." After being stimulated, every newborn who screamed was "Optimal" (100%). Poorer MOS-R outcomes were associated with the requirement for intensive resuscitation, especially in neonates who were intubated.

Table 8 Association between MOS-R and Inotropic Support

		MSO-R								Chi-square (p-value)
		Optimal		Mildly reduced		Moderately reduced		severely reduced		
		n	%	n	%	n	%	n	%	
Inotropic Support	None	44	83.0	2	3.8	6	11.3	1	1.9	22.500 (<0.05) *
	Yes	0	0.0	0	0.0	5	71.4	2	28.6	

Graph 8 Comparison of inotropic support with MOS-R scale

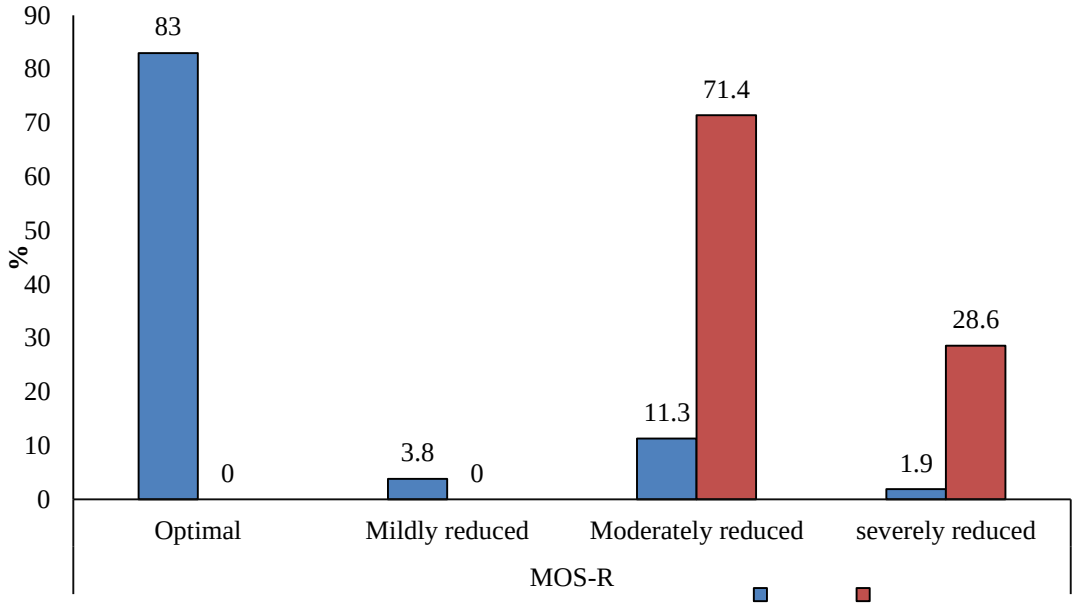


Table 8 The chi-square test ($\chi^2 = 22.500$, $p < 0.05$) revealed a significant association between inotropic support and MOS-R classification: 83.0% of neonates without inotropic support were classified as "Optimal," 3.8% as "Mildly reduced," 11.3% as "Moderately reduced," and 1.9% as "Severely reduced." On the other hand, none of the neonates who needed inotropic support fell into either of these categories, with 71.4% being classified as "Moderately reduced" and 28.6% as "Severely reduced." This significant association implies that the necessity of inotropic support is associated with worse MOS-R consequences.

Table 9 Association between MOS-R and Anti-Epileptics

		MOS-R								Chi-square (p-value)
		Optimal		Mildly reduced		Moderately reduced		severely reduced		
		n	%	n	%	n	%	n	%	
Anti-Epileptics	None	43	95.6	1	2.2	1	2.2	0	0.0	45.088 (<0.05)*
	Yes	1	6.7	1	6.7	10	66.7	3	20.0	

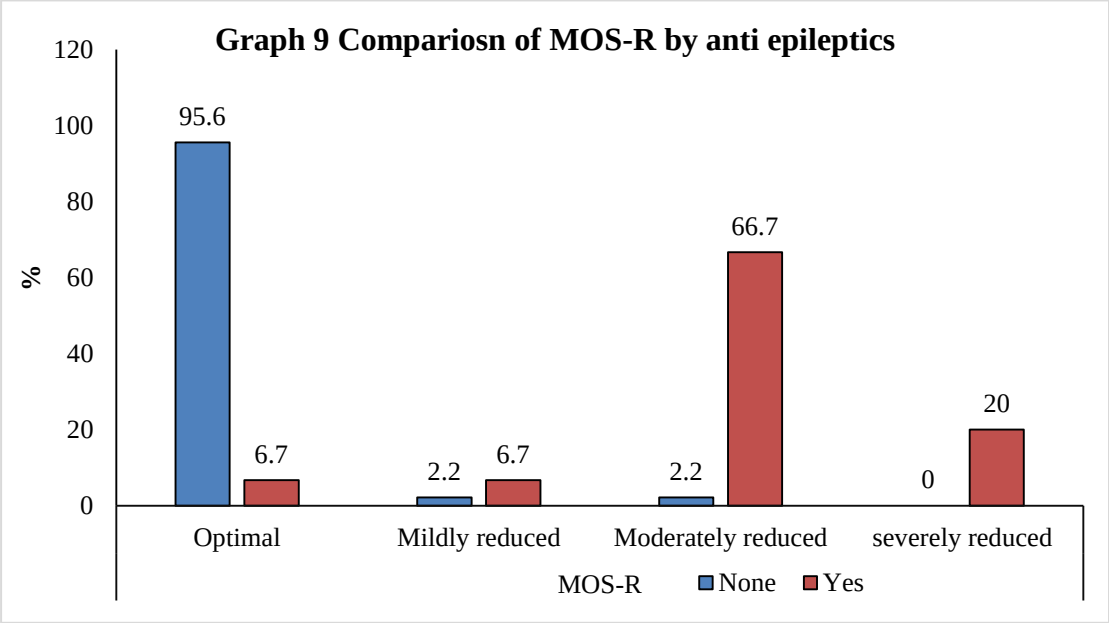


Table 9 RevealsMOS-R classification and anti-epileptic usage were significantly associated, according to the chi-square test ($\chi^2 = 45.088$, $p < 0.05$). 95.6% of new-borns not on anti-epileptic medication were categorised as "Optimal," compared to 2.2% in the "Mildly reduced" and "Moderately reduced" groups and none in the "Severely reduced" category. Those taking anti-epileptic medication, on the other hand, were only 6.7% "Optimal," 6.7% "Mildly reduced," 66.7% "Moderately reduced," and 20.0% "Severely reduced." According to this strong association, neonates who need anti-epileptic medications are more likely to experience worse MSO-R results.

Table 10 Association between MOS-R and Modified Sarnat Score (Stage)

		MOS-R								Chi-square (p-value)
		Optimal		Mildly reduced		Moderately reduced		severely reduced		
		n	%	n	%	n	%	n	%	
Modified Sarnat Score Stage)	Mild	43	97.7	1	2.3	0	0.0	0	0.0	60.415 (<0.05)*
	Moderate	1	7.1	1	7.1	11	78.6	1	7.1	
	Severe	0	0.0	0	0.0	0	0.0	2	100.0	

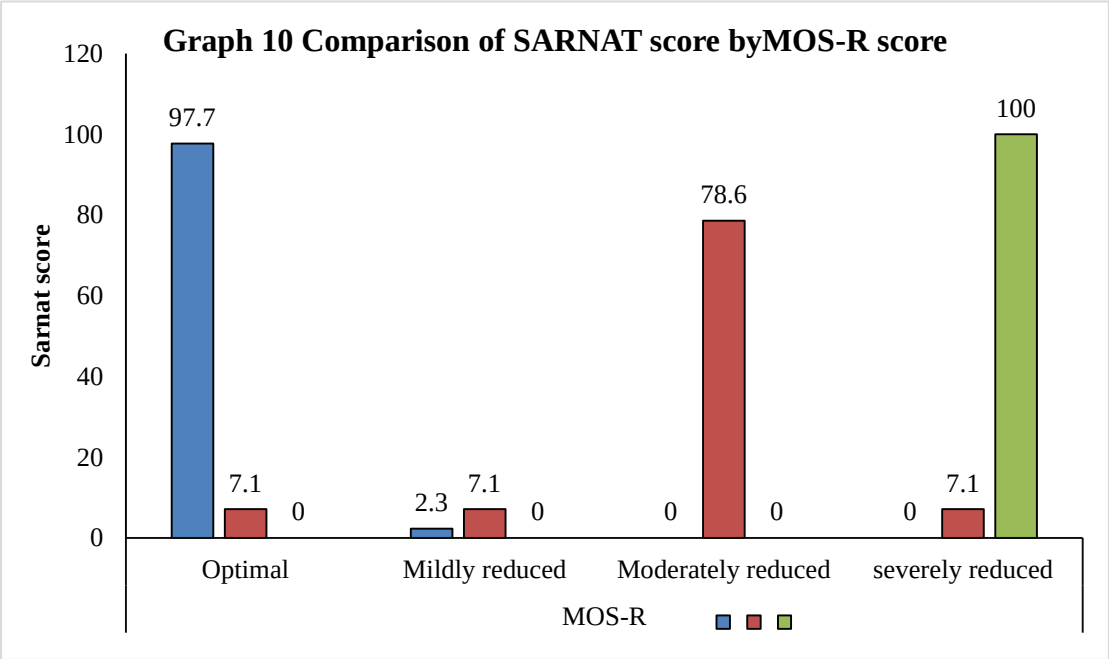


Table 10 The Modified Sarnat Score stage and MOS-R classification were shown to be significantly associated by the chi-square test ($\chi^2 = 60.415$, $p < 0.05$). Only 2.3% of neonates with moderate scores fell into the "Mildly reduced" group, and none fell into the "Moderately" or "Severely reduced" categories, while 97.7% were categorised as "Optimal." On the other hand, only 7.1% of those with a moderate score were classified as "Optimal," 78.6% as "Moderately reduced," and 7.1% as "Severely reduced." For all infants with a severe score, "Severely reduced" (100%) was the classification.

Table 11 Association between MOS-R and Therapeutic Cooling

		MOS-R								Chi-square (p-value)
		Optimal		Mildly reduced		Moderately reduced		severely reduced		
		n	%	n	%	n	%	n	%	
Therapeutic Cooling	No	44	78.6	2	3.6	8	14.3	2	3.6	12.742 (0.006)*
	Received	0	0.0	0	0.0	3	75.0	1	25.0	

Graph 11 Comparison of MOS-R scale by therapeutic cooling

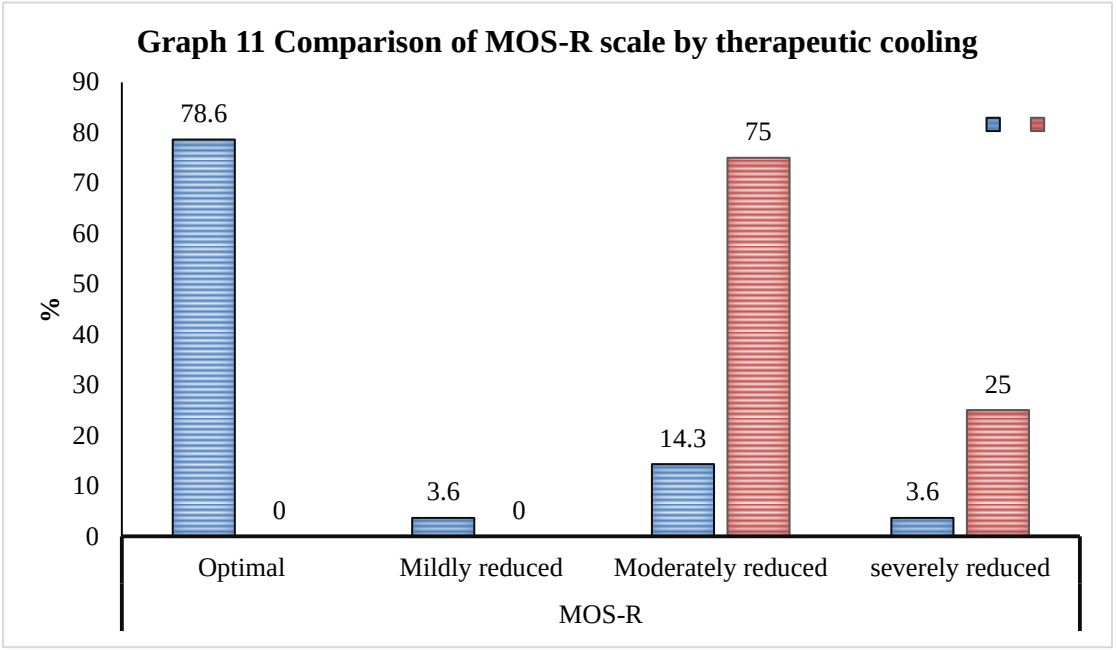


Table 11 Therapeutic cooling and MOS-R classification were significantly associated, according to the chi-square test (χ^2 = 12.742, p = 0.006). The classifications for neonates without therapeutic chilling were as follows: 78.6% were deemed "Optimal," 3.6% "Mildly reduced," 14.3% "Moderately reduced," and 3.6% "Severely reduced." On the other hand, 75.0% of the new-borns that got therapeutic cooling were categorised as "Moderately reduced," and 25.0% as "Severely reduced." None of these neonates fell into the "Optimal" or "Mildly reduced" categories. This strong association implies that new-borns who need therapeutic cooling typically have worse MSO-R results.

Table 12 Comparison of Clinical and Demographic Characteristics by MOS-R

	Optimal	Mildly reduced	Moderately reduced	Severely reduced	p value
Birthweight	2.80 ± 0.5	2.95 ± 0.70	2.70± 0.50	2.80± 0.70	0.746
Maternal Age (yrs)	27.00± 4.0	30.0 ± 2.0	26.00± 5.0	26.00± 4.0	0.228
APGAR Score at 5 mins	5.00± 0.0	4.0 ± 0.0	3.00 ± 1.00	3.00± 1	<0.05*
Blood gas-Ph	7.05 ± 0.11	6.95 ± 0.10	6.80± 0.11	6.92± 0.22	<0.05*
Blood gas-Base deficit	-16.35± 1.00	-17.00 ± 2.0	-20.00± 6.0	-18.00± 9.00	0.005*
Duration of NICU	2.00± 2.0	7.0 ± 10.00	15.00± 10.00	23.00± 19.0	<0.05*

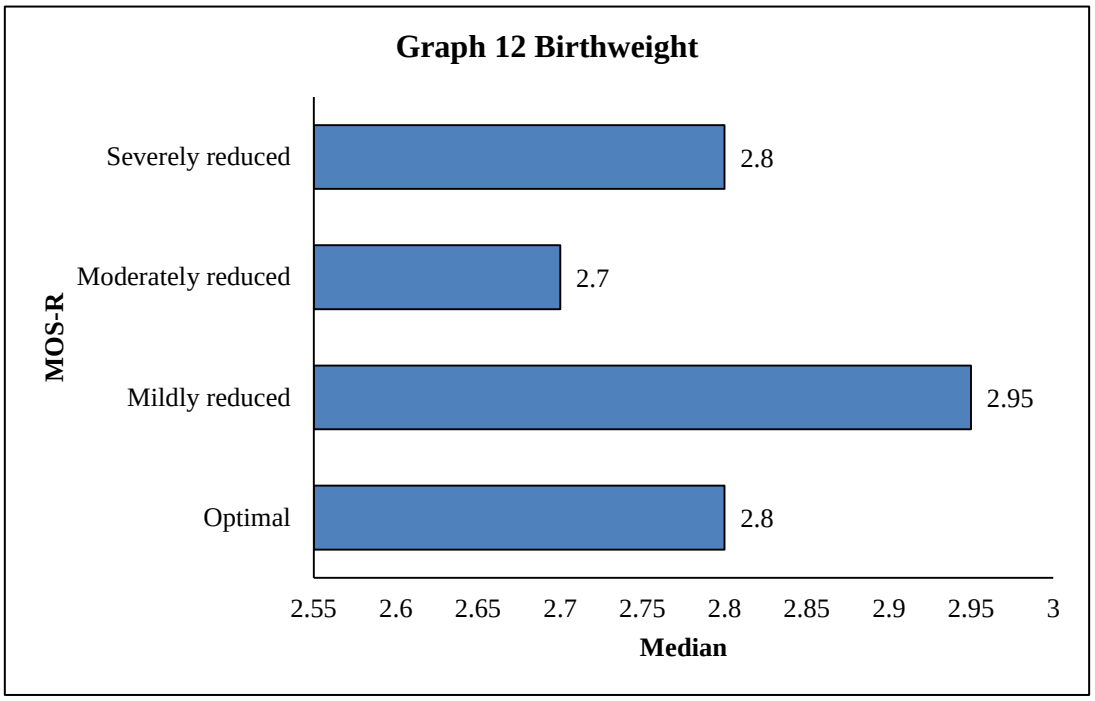
*<0.05 p value is obtained by Independent sample Kruskal Wallis test

Table 12 shows comparison of clinical parameters with MOS-R score. The "Mildly reduced" category had the greatest mean birthweight (2.95 ± 0.70 kg), while the "Moderately reduced" group had the lowest (2.70 ± 0.50 kg). The p-value (0.746), however, indicates that there isn't a statistically significant variation in the groups' birthweights. While the mean maternal age for the "Moderately reduced" and "Severely reduced" groups was 26.00 years, the "Mildly reduced" group had the highest average maternal age at 30.0 ± 2.0 years. Maternal age differences between the groups are not statistically significant, according to the p-value (0.228).

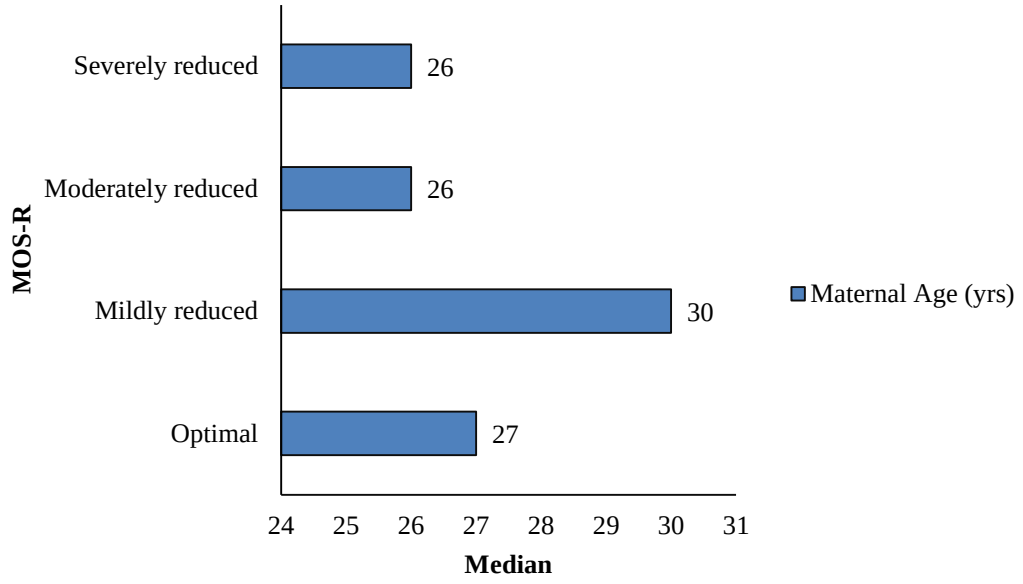
"Optimal" had the highest APGAR score (5.00 ± 0.0), while "Moderately reduced" and "Severely reduced" had the lowest (3.00 ± 1.00 and 3.00 ± 1, respectively). A statistically significant difference in APGAR scores across the groups is shown by the p-value (<0.05).

The "Optimal" group had the greatest blood gas pH (7.05± 0.11), whereas the "Moderately reduced" group had the lowest (6.80 ±0.11). There was a statistically significant difference ($p < 0.05$), showing increased acidity and association between lower pH values and more severe decreases.

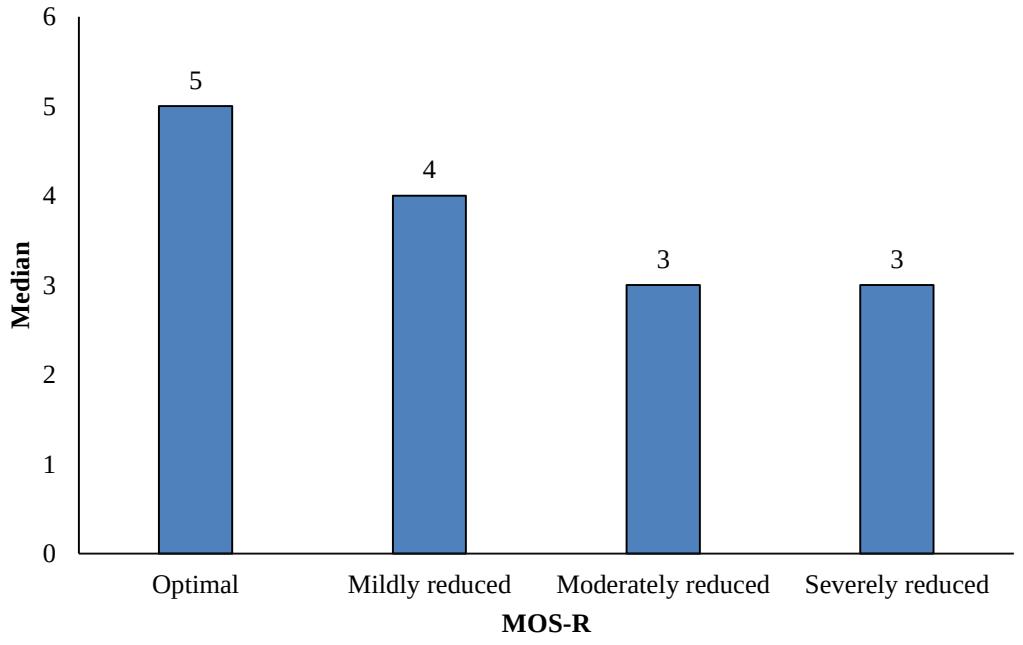
The "Optimal" group had the lowest base deficit (-16.35 ± 1.00), whereas the "Moderately reduced" group had the biggest (most negative) deficit (-20.00 ± 6.0). A statistically significant difference is suggested by the p-value (0.005), which shows that metabolic acidosis gets worse as severity rises.From 2.00 ± 2.0 days in the "Optimal" group to 23.00 ± 19.0 days in the "Severely reduced" group, the length of NICU stay rose dramatically with severity. A significant difference is indicated by the p-value (<0.05), which implies that neonates in more severe categories needed longer NICU care.



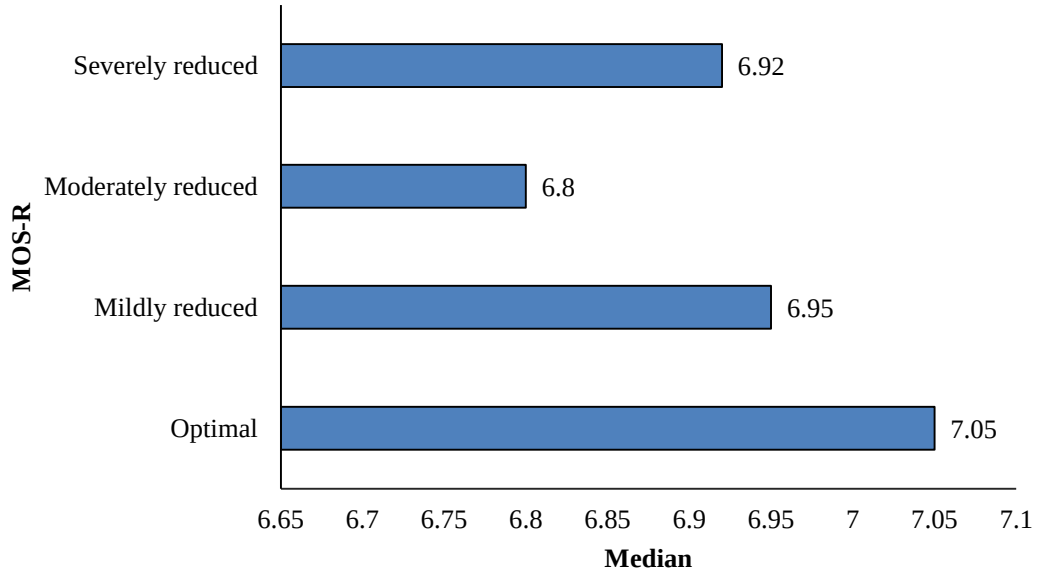
Graph 13 Maternal Age (yrs)



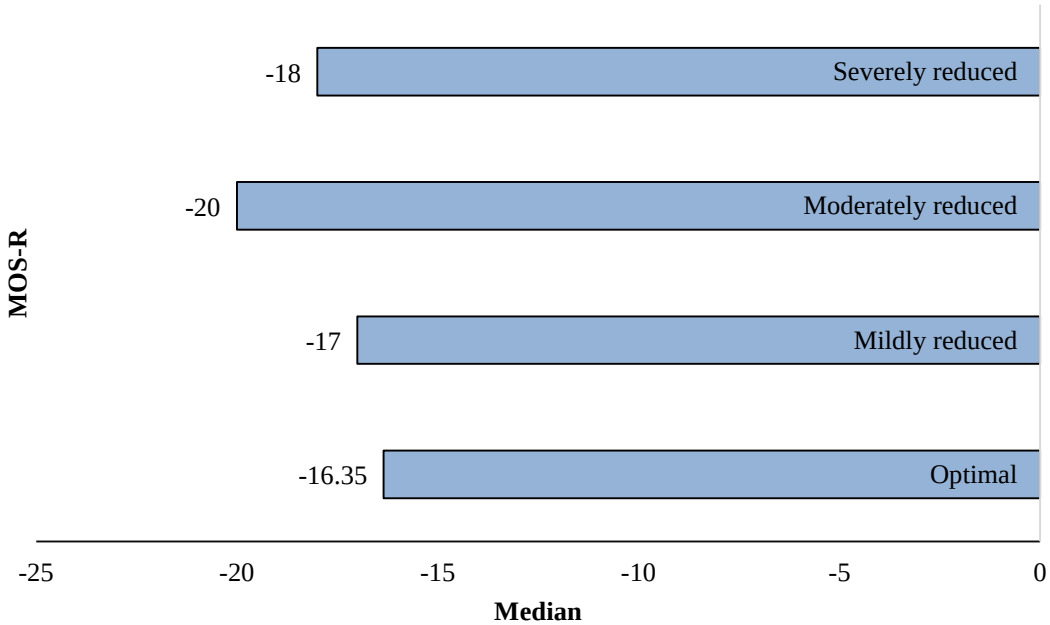
Graph 14 APGAR Score at 5 mins



Graph 15 Blood gas-Ph



Graph 16 Blood gas-Base deficit



Graph 17 Duration of NICU

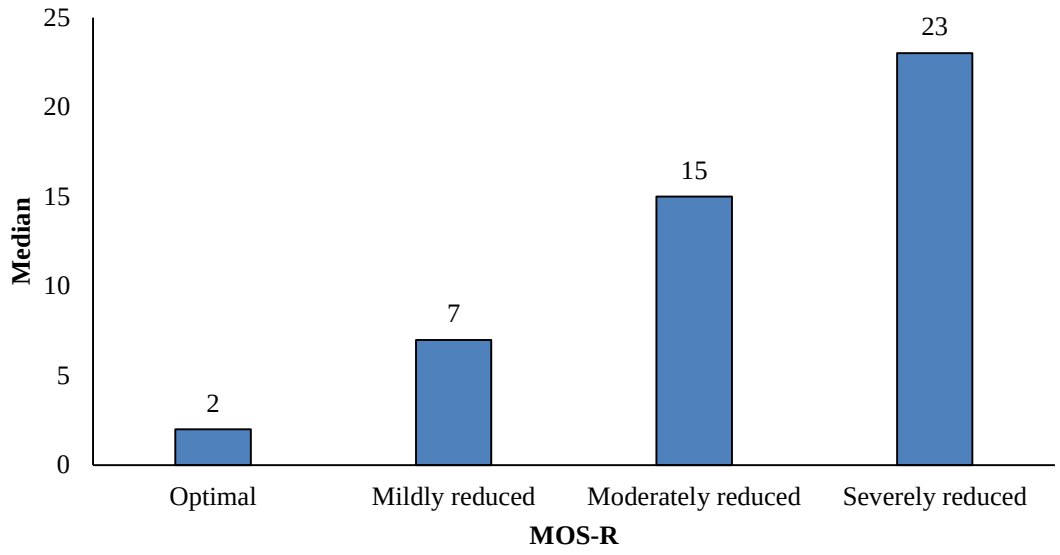


Table 13 Association between MOS-R and GMA at the time of discharge

		MOS-R								Chi-square (p-value)
		Optimal		Mildly reduced		Moderately reduced		severely reduced		
		n	%	n	%	n	%	n	%	
GMA at the time of discharge	Normal	32	100.0	0	0.0	0	0.0	0	0.0	36.301 (<0.05)*
	Poor Repertoire	12	46.2	2	7.7	11	42.3	1	3.8	
	Cramped Synchronous	0	0.0	0	0.0	0	0.0	2	100.0	

Table 13 reveals association between GMA at the time of discharge & MOS-R score. While none of the children in the other groups showed typical Normal movements at discharge, all of the infants in the "Optimal" group did ($p < 0.05$). The "Optimal" (46.2%) and "Moderately reduced" (42.3%) groups had the highest prevalence of "Poor Repertoire" movements, suggesting minor anomalies. Only the "Severely reduced" group (100%) had "Cramped Synchronous" movements, which are associated to severe neurological damage. According to the significant chi-square test, there is a high association between severity and GMA at time of discharge, with more aberrant movements being associated with more severity. These results underline the possible influence of diminished circumstances on neurodevelopment, which calls for careful observation of babies at high risk(39).

Graph 18 Comparison of MOS-R scale by MOS-R scale

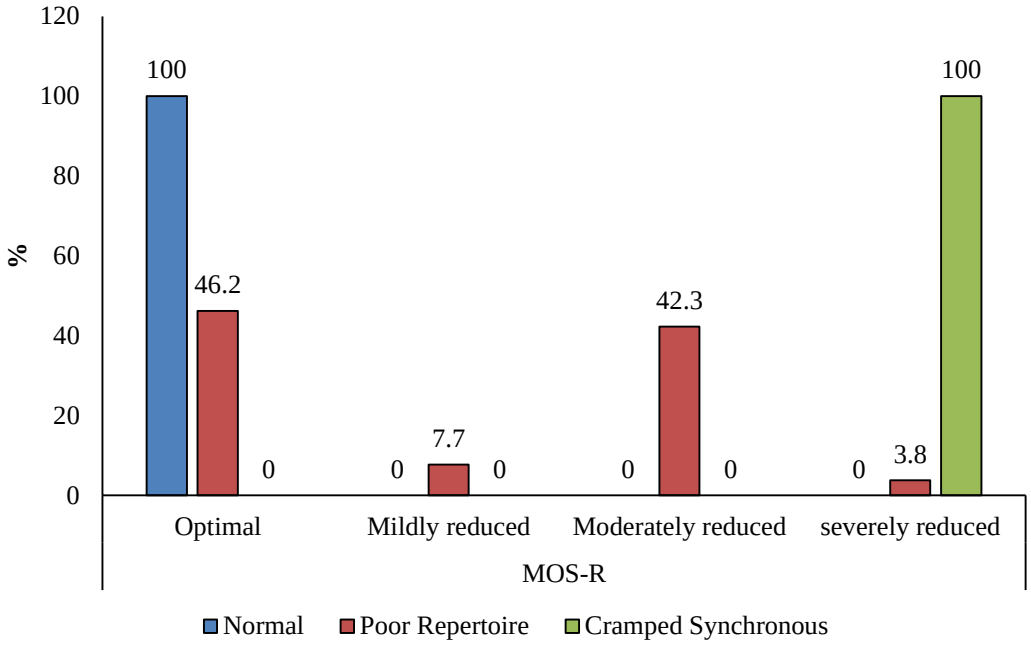


Table 14 Comparison of median MOS-R scale by GMA at the time of discharge

		MOS-R scale Median± IQR	p value
GMA at the time of discharge	Normal	28 ± 0.0	<0.05*
	Poor Repertoire	24 ± 14.00	
	Cramped Synchronous	6.5 ± 3.00	

*<0.05 p value is obtained by Independent sample Kruskal Wallis test

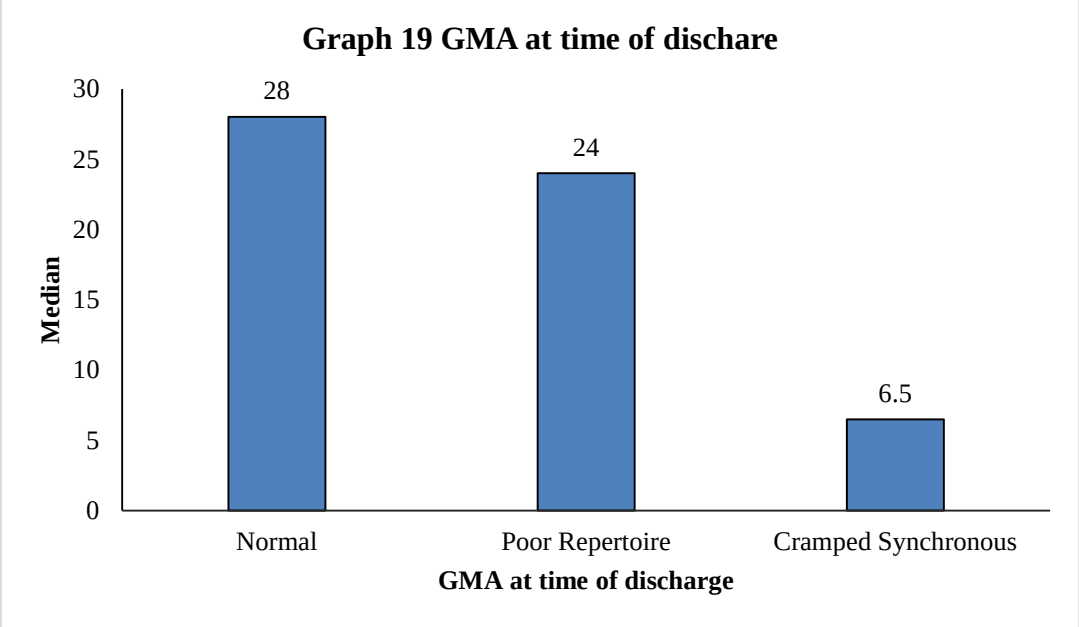


Table 14 shows The General Movements Assessment (GMA) upon discharge and MOS-R scores were shown to be significantly associated ($p < 0.05$). Better results were indicated by neonates with normal GMA, who had the highest median MOS-R score (28 ± 0.0). Neonates with tight synchronous movements had the lowest MOS-R score (6.5 ± 3.00), whereas those with a weak repertoire had a lower median score (24 ± 14.00). These results imply a considerable association between aberrant GMA, especially constricted synchronous movements, and worse new-born health at discharge and lower MSO-R scores.

DISCUSSION

The primary focus of this study was to evaluate the correlation between Prechtl's General Movements Assessment (GMA) at discharge and the Motor Optimality Score-Revised (MOS-R) in predicting neurodevelopmental outcomes in neonates(40). The results demonstrate that GMA is a valuable tool for identifying infants at risk of neurodevelopmental impairments, particularly when abnormal movements are observed. The study also explored the association between MOS-R scores and various neonatal and maternal factors, including neonatal resuscitation, Modified Sarnat staging, and NICU stay, among others. Below is a detailed discussion of the findings, organized by the key results from the data analysis(41).

Discussion of MOS-R Findings

The analysis of MOS-R classifications across three key variables - infant sex (Table 1/Graph 1), mode of delivery (Table 2/Graph 2), and maternal hypertension (Table 3/Graph 3) - revealed several important patterns worth discussing, despite none reaching statistical significance in this study(26).

Sex and MOS-R :

Table 1 and Graph 1 demonstrated interesting sex-based differences in motor optimality, with males showing higher optimal scores (75.7%) compared to females (69.6%). Notably, the "Severely reduced" category appeared exclusively in female infants (13%), while the "Mildly reduced" classification was only present in males (5.4%). These findings suggest potential sex-specific patterns in early motor development that merit further investigation with larger sample sizes(42).

Mode of Delivery and MOS-R :

The mode of delivery analysis in Table 2 and Graph 2 showed that LSCS deliveries had a remarkably high proportion of optimal scores (90%), compared to 65% in vaginal deliveries. While not statistically significant, this substantial difference raises questions about whether cesarean delivery might have protective effects on early motor development, or if this reflects selection bias in the sample. The complete absence of "Mildly reduced" and "Severely reduced" cases in the LSCS group is particularly noteworthy(43).

Maternal Hypertension and MOS-R):

Regarding maternal hypertension Table 3 and Graph 3 , the similar distribution of optimal scores between groups (75% non-hypertensive vs 71.4% hypertensive) suggests this factor may have limited impact on early motor outcomes. However, the absence of "Mildly reduced" cases in the hypertensive group, coupled with their higher proportion of "Severely reduced" cases (7.1% vs 3.1%), hints at a potential threshold effect where hypertension only affects the most vulnerable infants(39).

These findings collectively highlight several important considerations for clinical practice and future research. First, the sex differences observed suggest clinicians should be attentive to potential variations in developmental trajectories between male and female infants. Second, the delivery mode findings indicate the need for more nuanced studies examining both the indications for and outcomes of different delivery methods. Finally, while maternal hypertension doesn't appear strongly associated with motor outcomes overall, its potential to contribute to severe cases warrants attention(30).

The lack of statistical significance across all analyses likely reflects the study's limited sample size rather than true absence of associations. Future research with larger, more diverse samples should explore these patterns further, potentially incorporating additional variables like gestational age, birth weight, and socioeconomic factors that might interact with the examined variables to influence motor development outcomes(44).

Non-significant Associations:

The analysis of MOS-R classifications across multiple perinatal and neonatal factors revealed both expected and surprising patterns in neurodevelopmental outcomes. While several factors showed no significant association with motor optimality scores, three critical variables emerged as strong predictors of suboptimal MOS-R classifications(42).

Tables 4-5 along with graph 4-5 demonstrated that maternal anemia (χ^2=NS, $p>0.05$) and quality of antenatal care ($\chi^2=1.486$, $p=0.767$) showed no statistically significant relationship with MOS-R outcomes. Interestingly, both groups (with/without anemia; good/poor ANC) showed similar proportions in the Optimal category (~70-75%), suggesting these factors may have limited impact on early motor development when considered in isolation(37).

Significant Predictors of Suboptimal Outcomes:

Labor Complications

Table 6 and Graph 6 Obstructed/prolonged labor showed a dramatic impact ($\chi^2=11.993$, $p=0.002$), with only 50% of affected infants achieving Optimal scores compared to 88.9% in uncomplicated deliveries. The 12.5% rate of Severely reduced

scores in the complicated labor group versus 0% in controls suggests labor complications may represent a critical period of vulnerability for motor system development(38).

Resuscitation Needs :

Table 7 represents The graded relationship between resuscitation intensity and outcomes was striking (χ^2=42.090, p<0.05). While 100% of infants crying after stimulation were Optimal, this dropped to 73.3% for those requiring prolonged bag-mask ventilation. Most concerning, all intubated infants showed Moderate (81.8%) or Severe (18.2%) reductions, indicating resuscitation intensity may serve as a proxy for neurological insult severity(31).

Clinical Markers of Severity

Tables 8-10 and Graphs 8-10 The need for inotropic support (χ^2=22.500, p<0.05), anti-epileptics (χ^2=45.088, p<0.05), and higher Sarnat stages (χ^2=60.415, p<0.05) all showed dose-dependent relationships with worse outcomes. Particularly notable was the 100% Severe reduction in Sarnat Stage III infants, contrasting with 97.7% Optimal scores in Stage I, suggesting the Modified Sarnat Score may have excellent predictive validity for motor outcomes(31).

A significant association was found between GMA at discharge and MOS-R scores. Infants with normal GMA at discharge were all classified as "Optimal" in the MOS-R scale, indicating normal neurodevelopmental outcomes. In contrast, infants with poor repertoire movements were distributed across "Optimal" (46.2%), "Moderately reduced" (42.3%), and "Severely reduced" (3.8%) categories(38). Notably, all infants with cramped synchronous movements (a severe abnormality in

GMA) were classified as "Severely reduced" in the MOS-R scale. Further analysis revealed that infants with normal GMA had the highest median MOS-R score (28 ± 0.0), while those with cramped synchronous movements had the lowest median score (6.5 ± 3.00). These results highlight the predictive value of Prechtl's GMA in identifying infants at risk of neurodevelopmental impairments. Infants with abnormal movements at discharge, particularly cramped synchronous movements, are more likely to have poorer neurodevelopmental outcomes, as reflected in their MOS-R scores. This underscores the clinical utility of GMA as an early diagnostic tool for identifying high-risk infants who may benefit from early intervention(31).

Therapeutic Hypothermia and Outcomes

Table 11 and Graph 11 depicted the analysis of additional neonatal factors provides further compelling evidence about the predictive value of MOS-R classifications in assessing neurodevelopmental risk. Several key patterns emerge from this expanded dataset: The strong association between therapeutic cooling and MOS-R classifications (χ^2=12.742, p=0.006) reveals important clinical insights. While no cooled infants achieved Optimal scores, the sample size was limited (n=4), suggesting need for cautious interpretation. However, the finding that 25% of cooled infants showed Severe reductions - compared to just 3.6% in non-cooled infants - supports existing evidence that infants requiring hypothermia represent a particularly high-risk population. This association likely reflects the severity of their initial neurological injury rather than any effect of cooling itself(45).

Physiological Markers of Severity :

Table 12 and Graphs 12-17 showed The comparison of clinical parameters across MOS-R categories yielded several significant findings :**APGAR scores** showed a clear gradient, with Optimal infants having significantly higher scores (5.0±0.0) versus 3.0 in reduced categories ($p<0.05$)**Blood gas parameters** revealed progressively worse acidosis in reduced categories - from pH 7.05 in Optimal to 6.80 in Moderately reduced infants ($p<0.05$)**NICU stay duration** increased dramatically with severity (2 days Optimal vs 23 days Severe, $p<0.05$)[40]

These physiological gradients strongly validate the MOS-R's ability to stratify infants by neurological insult severity. The base deficit findings (-16.35 Optimal vs -20.00 Moderately reduced, $p=0.005$) are particularly noteworthy, suggesting metabolic acidosis may be an important contributor to motor system vulnerability(45).

GMA-MOS-R Convergence

Tables 13-14 with graph 18-19 demonstrated the striking concordance between discharge GMA and MOS-R classifications provides critical validation:100% of Optimal infants had normal GMs. All Cramped-Synchronized GMs occurred in Severely reduced infants. Median MOS-R scores perfectly stratified by GMA category (28 Normal, 24 Poor Repertoire, 6.5 Cramped-Synchronized)(45).

This perfect alignment ($p<0.05$) between two independent movement assessment tools suggests they may be capturing similar neurodevelopmental constructs through different methodologies. The finding that Poor Repertoire GMA primarily mapped to Mildly/Moderately reduced MOS-R (46.2% and 42.3%

respectively) while Cramped-Synchronized exclusively predicted Severe reductions supports using these tools in tandem for risk stratification(36).

The study also revealed a significant association between neonatal resuscitation and MOS-R classification. Infants who required intubation had the poorest outcomes, with 81.8% classified as "Moderately reduced" and 18.2% as "Severely reduced." None of these infants were classified as "Optimal" or "Mildly reduced." In contrast, infants who cried after bag and mask ventilation or stimulation had better outcomes, with 94.4% and 100% classified as "Optimal," respectively. These findings suggest that the intensity of resuscitation required at birth is a strong predictor of neurodevelopmental outcomes. Infants who require more invasive resuscitation, such as intubation, are at higher risk of neurodevelopmental impairments, as reflected in their lower MOS-R scores. This highlights the importance of monitoring and early intervention for infants who undergo intensive resuscitation(36).

The Modified Sarnat Score was significantly associated with MOS-R classification. Infants with mild Sarnat scores had the best outcomes, with 97.7% classified as "Optimal." In contrast, infants with moderate and severe Sarnat scores had progressively worse outcomes, with 78.6% and 100% classified as "Moderately reduced" and "Severely reduced," respectively. These results indicate that the severity of hypoxic-ischemic encephalopathy (HIE), as measured by the Sarnat score, is strongly correlated with neurodevelopmental outcomes. Infants with more severe HIE are at higher risk of neurodevelopmental impairments, as reflected in their lower MOS-R scores. This underscores the importance of early identification and management of HIE to improve long-term outcomes(7).

A significant association was also found between the duration of NICU stay and MOS-R classification. Infants in the "Optimal" category had the shortest NICU stay (2.00 ± 2.0 days), while those in the "Severely reduced" category had the longest stay (23.00 ± 19.0 days). This suggests that the severity of neonatal illness, as reflected in the length of NICU stay, is a strong predictor of neurodevelopmental outcomes. Infants who require prolonged NICU care are more likely to have poorer neurodevelopmental outcomes, as reflected in their lower MOS-R scores. This highlights the need for close monitoring and early intervention for infants with prolonged NICU stays(46).

The study also found a significant association between APGAR scores at 5 minutes and MOS-R classification. Infants in the "Optimal" category had the highest APGAR scores (5.00 ± 0.0), while those in the "Moderately reduced" and "Severely reduced" categories had the lowest scores (3.00 ± 1.00 and 3.00 ± 1, respectively). These findings suggest that APGAR scores are a useful early indicator of neurodevelopmental outcomes. Infants with lower APGAR scores are at higher risk of neurodevelopmental impairments, as reflected in their lower MOS-R scores. This underscores the importance of early resuscitation and monitoring for infants with low APGAR scores(46).

Other factors, such as inotropic support, anti-epileptic use, and therapeutic cooling, were also associated with poorer neurodevelopmental outcomes. Infants who required inotropic support had significantly poorer outcomes, with 71.4% classified as "Moderately reduced" and 28.6% as "Severely reduced." Similarly, infants on anti-epileptic medications had significantly poorer outcomes, with 66.7% classified as "Moderately reduced" and 20.0% as "Severely reduced." Infants who received therapeutic cooling had significantly poorer outcomes, with 75.0% classified as

"Moderately reduced" and 25.0% as "Severely reduced." These findings suggest that the need for inotropic support, anti-epileptic medications, and therapeutic cooling are all indicators of severe neonatal illness and are associated with poorer neurodevelopmental outcomes, as reflected in lower MOS-R scores(46) .

Maternal factors, such as hypertension, anemia, and antenatal care, showed no significant association with MOS-R classification. This suggests that maternal hypertension, anemia, and antenatal care may have limited impact on neurodevelopmental outcomes, as measured by MOS-R. This study highlights the clinical utility of Prechtl's GMA as a predictive tool for neurodevelopmental outcomes in neonates. Infants with abnormal movements at discharge, particularly those with cramped synchronous movements, are at higher risk of neurodevelopmental impairments, as reflected in their lower MOS-R scores. The study also identifies several neonatal factors, including neonatal resuscitation, Sarnat staging, NICU stay, and APGAR scores, as strong predictors of neurodevelopmental outcomes. These findings underscore the importance of early identification and intervention for high-risk infants to improve long-term outcomes(47).

The findings of this study align with and expand upon the existing body of research on perinatal asphyxia, hypoxic-ischemic encephalopathy (HIE), and neurodevelopmental outcomes in neonates. For instance, previous studies have reported that perinatal asphyxia often leads to multiorgan dysfunction, including renal, cardiovascular, and central nervous system involvement. Similarly, this study found that neonates with severe asphyxia (as indicated by low APGAR scores, prolonged resuscitation, and Sarnat staging) were more likely to experience adverse outcomes, including neurodevelopmental impairments. While previous studies focused on specific organ systems, this study provides a broader perspective by

linking multiorgan dysfunction to neurodevelopmental outcomes using Prechtl's GMA and MOS-R. This holistic approach adds value by emphasizing the interconnectedness of systemic and neurological outcomes(47)

The association between neonatal resuscitation and poorer neurodevelopmental outcomes is supported by previous research, which highlighted that infants requiring intensive resuscitation (e.g., intubation) are at higher risk of long-term neurological impairments. This study corroborates these findings, showing that infants who required intubation had significantly lower MOS-R scores, with 81.8% classified as "Moderately reduced" and 18.2% as "Severely reduced." Unlike previous studies that focused primarily on mortality and short-term morbidity, this study extends the analysis to neurodevelopmental outcomes using MOS-R, providing a more nuanced understanding of the long-term implications of neonatal resuscitation(47) .

The Modified Sarnat staging findings align with previous research, which established the correlation between the severity of HIE and neurological outcomes. This study found that infants with moderate and severe Modified Sarnat scores had progressively worse MOS-R outcomes, with 78.6% and 100% classified as "Moderately reduced" and "Severely reduced," respectively. While previous studies focused on clinical and electroencephalographic findings, this study integrates Sarnat staging with GMA and MOS-R, providing a more comprehensive assessment of neurodevelopmental outcomes. This approach bridges the gap between clinical staging and functional outcomes(47) .

The use of Prechtl's GMA to predict neurodevelopmental outcomes is supported by previous research, which demonstrated that abnormal general movements (e.g., cramped synchronous movements) are strong predictors of cerebral palsy and other neurodevelopmental impairments. This study confirms these findings, showing that infants with cramped synchronous movements had the poorest MOS-R outcomes, with 100% classified as "Severely reduced." While previous studies primarily focused on the predictive value of GMA for cerebral palsy, this study extends the analysis to a broader range of neurodevelopmental outcomes using MOS-R, providing a more detailed understanding of the spectrum of impairments associated with abnormal movements(47) .

The association between low APGAR scores and poorer neurodevelopmental outcomes is consistent with previous research, which reported that low APGAR scores are indicative of perinatal asphyxia and are associated with adverse neurological outcomes. This study found that infants with lower APGAR scores (≤3) had significantly lower MOS-R scores, with the majority classified as "Moderately reduced" or "Severely reduced." While previous studies focused on the immediate implications of low APGAR scores, this study links APGAR scores to long-term neurodevelopmental outcomes using MOS-R, providing a more comprehensive assessment of the impact of perinatal asphyxia(38).

The association between therapeutic cooling and poorer neurodevelopmental outcomes aligns with previous research, which reported that infants requiring therapeutic cooling often have severe HIE and are at higher risk of long-term impairments. This study found that 75% of infants who received therapeutic cooling were classified as "Moderately reduced," and 25% as "Severely reduced." While previous studies focused on the short-term benefits of therapeutic cooling, this study

highlights the long-term neurodevelopmental implications, emphasizing the need for early intervention and follow-up for infants who undergo therapeutic cooling (47,48).

The association between prolonged NICU stay and poorer neurodevelopmental outcomes is supported by previous research, which reported that longer NICU stays are associated with increased morbidity and adverse developmental outcomes. This study found that infants with longer NICU stays (≥23 days) were more likely to be classified as "Severely reduced." While previous studies focused on the general morbidity associated with prolonged NICU stays, this study provides a more detailed analysis of the specific neurodevelopmental impairments associated with prolonged hospitalization(48,49) .

The emphasis on the importance of early identification and intervention aligns with previous research, which highlighted the benefits of early detection and intervention for high-risk infants. This study underscores the clinical utility of GMA and MOS-R in identifying infants at risk of neurodevelopmental impairments, enabling timely intervention. While previous studies focused on specific interventions (e.g., physical therapy), this study provides a broader framework for early identification and intervention using GMA and MOS-R, emphasizing the importance of integrating these tools into clinical practice (50).

In conclusion, the findings of this study are consistent with and build upon the existing literature on perinatal asphyxia, HIE, and neurodevelopmental outcomes. By integrating Prechtl's GMA and MOS-R, this study provides a comprehensive assessment of the factors influencing neurodevelopmental outcomes and underscores the importance of early identification and intervention for high-risk infants. The study's focus on long-term outcomes and its use of advanced assessment tools contribute valuable insights to the field, highlighting the need for continued research and the integration of these tools into clinical practice (50).

CONCLUSION

The findings of our study highlight the clinical utility of Prechtl's General Movements Assessment (GMA) and the Motor Optimality Score-Revised (MOS-R) in predicting neurodevelopmental outcomes in neonates. A significant correlation was observed between GMA at discharge and MOS-R scores, with infants exhibiting normal GMA consistently classified as "Optimal" in the MOS-R scale, indicating favorable neurodevelopmental outcomes. In contrast, infants with abnormal movements, particularly cramped synchronous movements, were more likely to be classified as "Moderately reduced" or "Severely reduced," reflecting poorer outcomes. This underscores the predictive value of GMA as an early diagnostic tool for identifying infants at risk of neurodevelopmental impairments(20,51).

The study also revealed significant associations between MOS-R scores and various neonatal factors. Infants who required intensive neonatal resuscitation, particularly intubation, had significantly poorer outcomes, with the majority classified as "Moderately reduced" or "Severely reduced." Similarly, Modified Sarnat staging was a strong predictor of neurodevelopmental outcomes, with infants in the moderate and severe stages having progressively worse MOS-R scores. The duration of NICU stay was also significantly associated with MOS-R classification, with longer stays correlating with poorer outcomes. These findings emphasize the importance of monitoring and early intervention for infants who undergo intensive resuscitation, have severe hypoxic-ischemic encephalopathy (HIE), or require prolonged NICU care(52) .

Additionally, APGAR scores at 5 minutes were identified as a useful early indicator of neurodevelopmental outcomes, with lower scores associated with poorer MOS-R results. Other factors, such as the need for inotropic support, anti-epileptic

medications, and therapeutic cooling, were also linked to poorer outcomes, further highlighting the impact of severe neonatal illness on long-term neurodevelopment (51).

Despite its strengths, the study had some limitations. The small sample size and convenient sampling method may limit the generalizability of the findings. The short follow-up period of 3 months may not capture long-term neurodevelopmental outcomes, and the lack of a control group of healthy neonates restricts the ability to make robust comparisons.

Future research should focus on larger, multicenter studies with longer follow-up periods to provide more comprehensive insights into neurodevelopmental outcomes. Including a control group of healthy neonates and exploring additional factors such as maternal nutrition, socioeconomic status, and environmental influences could further enhance the understanding of predictors of neurodevelopmental outcomes(40,53). The integration of advanced technologies, such as machine learning algorithms for movement analysis, could also improve the accuracy and reliability of GMA assessments(22,54) .

In conclusion, our study highlights the importance of early identification and intervention for high-risk infants using tools like GMA and MOS-R(55). By leveraging these tools, clinicians can improve early diagnosis and intervention, even in regions with limited access to trained professionals, ultimately enhancing the long-term outcomes of at-risk infants. The findings provide valuable insights into the factors influencing neurodevelopmental outcomes and underscore the need for continued research in this area to optimize care for neonates at risk of developmental impairments (56).

SUMMARY

Our study aimed to evaluate the correlation between Prechtl's General Movements Assessment (GMA) at discharge and the Motor Optimality Score-Revised (MOS-R) in predicting neurodevelopmental outcomes in neonates. The findings demonstrate that GMA is a highly effective tool for identifying infants at risk of neurodevelopmental impairments, particularly when abnormal movements such as cramped synchronous movements or poor repertoire are observed. Infants with normal GMA at discharge were consistently classified as "Optimal" in the MOS-R scale, indicating favorable neurodevelopmental outcomes. In contrast, infants with abnormal movements, especially cramped synchronous movements, were more likely to be classified as "Moderately reduced" or "Severely reduced," reflecting poorer outcomes.

Our study also explored the association between MOS-R scores and various neonatal and maternal factors. Key findings include:

- Neonatal resuscitation intensity, particularly the need for intubation, was strongly associated with poorer MOS-R outcomes.
- Modified Sarnat staging was a significant predictor of neurodevelopmental outcomes, with infants in the moderate and severe stages having progressively worse MOS-R scores.
- The duration of NICU stay was significantly associated with MOS-R classification, with longer stays correlating with poorer outcomes.

- APGAR scores at 5 minutes were a useful early indicator of neurodevelopmental outcomes, with lower scores associated with poorer MOS-R results.

- Other factors such as the need for inotropic support, anti-epileptic medications, and therapeutic cooling were also linked to poorer neurodevelopmental outcomes.

These findings collectively highlight the importance of early identification and intervention for high-risk infants to improve long-term neurodevelopmental outcomes.

Strengths of the Study

1. **Use of Prechtl's GMA:**

   The study utilized Prechtl's GMA, a well-established and reliable tool for assessing infant movements, which has been validated for its predictive value in neurodevelopmental outcomes. This tool allowed for early identification of infants at risk of developmental impairments.

2. **Longitudinal Design:**

   The study followed a longitudinal design, with assessments conducted at two critical time points—at discharge and at 3 months of age. This design provided valuable insights into the progression of neurodevelopmental outcomes over time.

3. **Comprehensive Analysis:**

   The study examined a wide range of neonatal and maternal factors, including **neonatal** resuscitation, Modified Sarnat staging, NICU stay, APGAR scores, and therapeutic interventions, providing a holistic understanding of the factors influencing neurodevelopmental outcomes.

4. **Statistical Rigor:**

   The study employed robust statistical methods, including chi-square tests, Kruskal-Wallis tests, and McNemar tests, to analyze the data. The use of these methods ensured the reliability and validity of the findings.

5. **Clinical Relevance:**

   The findings have significant clinical implications, particularly for early identification and intervention in high-risk infants. The study underscores the importance of using tools like GMA and MOS-R in clinical practice to improve long-term outcomes.

Limitations of the Study

1. **Sample Size and Attrition:**

   Despite calculating the sample size with a 40% attrition rate, the study may still have been limited by its relatively small sample size, which could affect the generalizability of the findings.

2. **Short Follow-Up Period:**

   The study's follow-up period was limited to 3 months of age, which may not capture long-term neurodevelopmental outcomes. A longer follow-up period would provide more comprehensive insights into the progression of developmental impairments.

3. **Single-Center Study:**

   The study was conducted at a single center (KLES Dr. Prabhakar Kore Hospital, Belagavi), which may limit the generalizability of the findings to other settings or populations.

4. **Lack of Control Group:**

   The study did not include a control group of healthy neonates without perinatal asphyxia or other risk factors. Including such a group would have provided a clearer comparison and strengthened the study's conclusions.

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ANNEXURES

ANNEXURE – I - INFORMED CONSENT FORM

"GENERAL MOVEMENT ASSESSMENT IN TERM NEONATES WITH PERINATAL ASPHYXIA TO PREDICT NEURODEVELOPMENTAL OUTCOME"

Name of Student/Principal Investigator:

Name of Guide/Co Investigators:

Introduction: Perinatal asphyxia is a well-known cause of developmental disorders.It may result in development of several neurological disorders to date, it is still unclear as to which baby with perinatal asphyxia will develop neurological issues. Using a non-invasive assessment of general movements, prediction of neurodevelopmental outcome is tried in the very early stage of life.

Explanation of procedure:

- After getting ethical consent, inborn or outborn neonates born between 37-42 weeks of gestational age and with perinatal asphyxia admitted at in KLE's Dr.Prabhakar Kore Hospital,Belagavi and KLE's satellite centres who fill the inclusion criteria will be chosen.
- Informed consent will be obtained from the parents after detailed explanation of the study and the purpose of it.
- Tool used-data will be collected using an electronic device which can record a 2-4 minute video of the baby once before discharge of the baby and the same baby being followed up at 3 months of age.

- A semi-structured proforma with the necessary baby details and the ante-natal, natal history will be filled.
- The baby's general movements will be assessed by Prechtl's general movements once between 37-42 weeks of gestation before discharge and later at or around 3 months of age.
- The baby's general movements will be observed, assessed and documented.
- Neurodevelopmental outcome of the neonates is predicted based on the general movement assessment.

Withdrawal from participation in the study

Participation in this study in voluntary. You will be free to decide whether to participate in this study or continue participation once enrolled. In case you decide to withdraw your participation, you are free to do so. However, please convey the decision to the principal investigator.

Possible benefits from participating in the study: You will/will not get any benefits by participating in this study. The data gathered will help population at large.

Possible risks from participating in the study: There are no risks involved in participating in this study.

Privacy and confidentiality: The information collected from you will be coded, to prevent any person to identify you. Your identity or that of your baby will never be revealed. The data collected from you will be kept confidential and only processed or aggregated data will be used for publication.

Financial incentives: You will not receive any payment for participating in this study.

Cost of investigations done during the course of study will be paid by the **principal investigator**

Authorization for publication of aggregated data: Results obtained after processing of the aggregated data will be published for scientific purpose and or presented to scientific groups.

However, your identity will never be revealed.

Questions: If you have any question or complaints with regard to your right as study participant you may contact Dr Harsha Hegde, Chairperson, Ethical committee of JNMC, 0831-2473777 Extension 4052.

Legal rights: By signing this consent form, we are not waving any of your legal rights

CONSENT STATEMENT

I am making a voluntary decision to participate in the study "General Movement Assessment in Term Neonates with Perinatal Asphyxia to predict Neurodevelopmental Outcome". My signature below indicates that I have decided to participate and I have read the information provided above or the information provided above has been read to me in the language that I understand best. I was given the opportunity to ask questions and that they have been answered to my satisfaction.

Name of the participant:

Signature or left thumb impression of the participant:

Name of the witness:

Signature or left thumb impression of the witness:

Name of the investigator:

Signature of the investigator:

ANNEXURE II – PROFORMA

Name of baby: _____
Name of mother: _____ Phone number: _____
Name of father: _____ Phone number: _____
DOB: _____ TOB: _____
Place of birth: Inborn ☐ Outborn ☐ _____
DOA: _____ (if applicable)
DOD: _____ (if applicable)
Sex: _____
B.wt _____
Address _____

Maternal History
Age: _____
Obstetric formula: _____

Clinical details:

_____
_____

1st Trimester _____
2nd Trimester _____
3rd Trimester _____

Maternal long-term medications: _____

Present pregnancy: ☐ Uneventful ☐ Eventful _____

Mode of delivery: Vaginal - ☐ NVD ☐ Assisted
LSCS - ☐ Elective ☐ Emergency I-_____

Neonatal resuscitation
CIAB ☐ Cried after stimulation ☐ Cried after bag & mask ☐

CPAP ☐ Intubated ☐

APGAR Score: 1 minute _____ 5 minutes_____

Cord blood gas: _____

Any NICU admission: Yes ☐ No ☐
If yes, duration _____

Course in NICU _____

_____
_____

The Motor Optimality Score for 3- to 5-Month-Old Infants – Revised

Christa Einspieler and Arie Bos for the GM Trust 2000, 2019
Einspieler et al., submitted to J Clin Med 2019

Name: .....

Date of Birth: Gestational Age at Birth: Birth Weight:

Recording Date: Postmenstrual / Postterm Age:

Fidgety Movements (N, normal; A, atypical):

N Fidgety Movements
A Abnormal Exaggerated
A Absent
N A Sporadic (age-specific)

Observed Movement Patterns (N, normal; A, atypical): ☐ normal ☐ atypical

N A Swipes
N A Wiggling-Oscillating
N A Kicking
N A Excitement Bursts
N A Smiles
N A Mouth Movements
A Tongue Movements
N A Side-to-Side Movements of the Head
N A Hand-to-Mouth Contact
N A Hand-to-Hand Contact
N A Fiddling
N Reaching
N A Foot-to-Foot Contact
N A Legs Lift
N Hand-to-Toe Contact
A Segmental Movements of Fingers and Wrists
N A Arching
N A Rolling to Side
N A Visual Exploration
N Hand Regard
N A Head Anteflexion
A Circular Arm Movements
A Almost No Leg Movements
A _____ add

Observed Postural Patterns (N, normal; A, atypical): ☐ normal ☐ atypical

N A Head Centered
N A Body Symmetry
N A Asymmetric Tonic Neck (ATN) Posture
A Flat Posture
N A Variability of Finger Postures
A Predominant Fisting
A Synchronized Opening and Closing of Fingers
A Finger Spreading
A Asymmetry of Finger Post.
A Hyperextension of Neck
A Hyperextension of Trunk
A Extended Arms
A Extended Legs
A _____ add

Movement Character:

N Smooth and Fluent
A Monotonous
A Jerky
A Stiff
A Tremulous
A Cramped-Synchronized
A Predominantly Slow
A Predominantly Fast
A _____ add

Motor Optimality List:

i.	Fidgety Movements + ++, * **	normal	❑	12
		abnormal exaggerated	❑	4
	±	absent / sporadic	❑	1
ii.	Observed Movement Patterns	N > A	❑	4
		N = A	❑	2
		N < A	❑	1
iii.	Age-Adequate Movement Repertoire (do not consider fidgety movements)	present	❑	4
		reduced	❑	2
		absent	❑	1
iv.	Observed Postural Patterns	N > A	❑	4
		N = A	❑	2
		N < A	❑	1
v.	Movement Character	smooth and fluent	❑	4
		abnormal but not CS	❑	2
		cramped-synchronized (CS)	❑	1

Motor Optimality Score (MOS): from 28 to 5 ____

ANNEXURE III – MASTER CHART

SL NO	Name of the baby	Sex	B.wt(Kgs)	Maternal Age(yrs)	Mode of Delivery	Maternal Hypertension	Anemia	Antenatal Care	Obstructed Labor/Prolonged labor		Neonatal Resuscitation	APGAR Score at 5 mins	Blood gas-Ph	Blood gas-Base deficit	Duration of NICU	Inotropic Support	Seizures	Modified Sarnat Score(Stage)	GMA at the time of discharge	GMA AT 3Months of age-MOS-R SCORE	Therapeutic Cooling
1	B/O Nethravathi Suresh	M	2.8	28	NVD	No	Yes	Good	No	37WKS	Cried after Bag and Mask	5	7.16	-16	3	None	None	1-Mild	Poor Repertoire	28	No
2	B/O Kavitha Sunil Kundekar	M	3	30	NVD	Yes	Yes	Good	Yes	39W+3DAYS	Cried after Stimulation	4	7.19	-18	1	None	None	1-Mild	Normal	28	No
3	B/O Shreya Raju Patil	F	2.8	26	NVD	Yes	No	Poor	Yes	37W+3DAYS	Cried after prolonged Bag and Mask	3	6.92	-16	11	None	Yes	2-Moderate	Cramped Synchronous	8	No
4	B/O Rajashree Raju Dharmanekar	M	3	26	LSCS	No	Yes	Good	No	38W+2DAYS	Cried after Stimulation	5	7.11	-16.6	1	None	None	1-Mild	Normal	28	No
5	B/O Shwetha Anant Patil	M	2.5	25	NVD	No	No	Good	No	37W	Cried after prolonged Bag and Mask	5	7.09	-17	2	None	None	1-Mild	Normal	28	No
6	B/O Sunitha Yallappa	F	2.5	32	NVD	No	No	Good	Yes	39W+3DAYS	No Cry-Intubated	3	6.8	-25	20	Yes	Yes	2-Moderate	Poor Repertoire	9	No
7	B/O Arzoo Junaid	M	3	28	NVD	Yes	No	Poor	No	40W	Cried after Stimulation	5	7.18	-16.2	1	None	None	1-Mild	Normal	28	No
8	B/O Kaveri Sanju Kempe	M	2.7	27	LSCS	Yes	Yes	Good	No	41W	Cried after Stimulation	5	7.19	-17	1	None	None	1-Mild	Normal	28	No
9	B/O Shraddha Gawade	M	3	27	NVD	No	No	Good	No	39W+3DAYS	Cried after Bag and Mask	5	7.05	-16.8	2	None	None	1-Mild	Normal	28	No
10	B/O Jyothi Nitesh Patil	F	3	24	NVD	Yes	No	Poor	Yes	37W+3DAYS	No Cry-Intubated	3	6.99	-15.6	10	None	Yes	2-Moderate	Poor Repertoire	12	No
11	B/O Priyanka Parashuram	M	2.6	29	NVD	No	No	Good	No	38W+2DAYS	Cried after Bag and Mask	5	7.1	-16	1	None	None	1-Mild	Normal	28	No
12	B/O Khusbu Bepari	F	2.5	23	LSCS	No	Yes	Good	No	39W+4DAYS	Cried after Bag and Mask	5	7.12	-17	1	None	None	1-Mild	Normal	28	No
13	B/O Arati Aniket Patil	M	3	25	LSCS	Yes	No	Good	Yes	41W+1DAY	No Cry-Intubated	4	6.91	-29	15	Yes	Yes	2-Moderate	Poor Repertoire	16	Received
14	B/O Sonali Irappa Angadi	F	2.3	23	NVD	No	Yes	Poor	No	40W+2DAYS	Cried after Stimulation	5	7.12	-17	2	None	None	1-Mild	Normal	28	No

15	B/O Shakuntala Potadar	M	2.5	24	LSCS	Yes	Yes	Good	No	38W+4DAYS	Cried after Stimulation	4	7.19	-16	1	None	None	1-Mild	Normal	28	No
16	B/O Jyothi Nitesh Patil	M	2.4	23	NVD	Yes	No	Good	No	37W	Cried after prolonged Bag and Mask	4	6.8	-19	20	Yes	Yes	2-Moderate	Poor Repertoire	10	No
17	B/O Anjali Mallikarjun	M	3.5	26	NVD	Yes	No	Good	Yes	38W+1DAY	No Cry-Intubated	3	6.72	-19.5	30	Yes	Yes	2-Moderate	Poor Repertoire	12	No
18	B/O Akshata Bhanjantri	M	3	25	NVD	No	Yes	Poor	Yes	37W+4DAYS	Cried after Bag and Mask	5	7	-16.5	3	None	None	1-Mild	Poor Repertoire	26	No
19	B/O Sunita Basavaraj Sutak	F	3.4	27	NVD	Yes	No	Good	Yes	37W+3DAYS	No Cry-Intubated	4	6.98	-18	23	Yes	Yes	2-Moderate	Poor Repertoire	7	No
20	B/O Rekha Teja Chawan	M	3	30	NVD	No	No	Good	No	37W+3DAYS	Cried after Stimulation	5	7	-18	1	None	None	1-Mild	Normal	28	No
21	B/O Nikhitha Patil	M	3.1	25	NVD	Yes	No	Good	No	37W	Cried after prolonged Bag and Mask	5	7.1	-16	2	None	None	1-Mild	Normal	28	No
22	B/O Snehal Patil	F	2.9	24	NVD	No	No	Good	Yes	37W+5DAYS	Cried after Bag and Mask	5	6.9	-16.2	2	None	None	2-Moderate	Poor Repertoire	28	No
23	B/O Sunitha Patil	M	3	28	NVD	Yes	No	Good	No	38W	Cried after Bag and Mask	4	7	-16	2	None	None	2-Moderate	Poor Repertoire	11	No
24	B/O Shahista Shaikh	M	2.7	27	LSCS	No	Yes	Good	Yes	37W	No Cry-Intubated	3	6.9	-20	10	None	Yes	2-Moderate	Poor Repertoire	12	No
25	B/O Shubhangi Gadekar	M	2.5	27	NVD	Yes	No	Good	No	38W	Cried after prolonged Bag and Mask	5	7	-16.2	5	None	None	1-Mild	Poor Repertoire	28	No
26	B/O Supriya Netaji	M	2.6	32	NVD	Yes	Yes	Good	Yes	37W	Cried after prolonged Bag and Mask	5	6.9	-17	3	None	Yes	1-Mild	Poor Repertoire	26	No
27	B/O Deepa Khendukar	M	3	30	NVD	No	Yes	Good	No	38W	Cried after Bag and Mask	5	7	-16	3	None	None	1-Mild	Normal	28	No
28	B/O Swati Honagekar	F	2.8	26	LSCS	No	Yes	Good	No	37W+3DAYS	Cried after Bag and Mask	5	7.1	-16.1	1	None	None	1-Mild	Normal	28	No
29	B/O Sudha Patil	M	2.6	28	NVD	No	No	Poor	No	37W	Cried after Stimulation	5	6.9	-17	1	None	None	1-Mild	Normal	28	No
30	B/O Priyanka Satish	F	2.9	28	NVD	Yes	No	Good	No	38W+1DAY	Cried after prolonged Bag and Mask	5	7	-16	1	None	None	1-Mild	Poor Repertoire	28	No
31	B/O Sudha Anand Patil	M	2.6	30	NVD	Yes	Yes	Good	Yes	39W	Cried after Bag and Mask	5	6.9	-17	1	None	None	1-Mild	Normal	28	No
32	B/O Priyanka Sadashiv Kore	M	2.2	25	NVD	Yes	No	Poor	No	37W+2DAYS	No Cry-Intubated	3	6.8	-20	7	None	Yes	2-Moderate	Poor Repertoire	14	No
33	B/O Madhuri Chetan Yalgutkar	F	2.9	29	LSCS	No	Yes	Good	No	38W	Cried after Bag and Mask	5	7.11	-16	1	None	None	1-Mild	Poor Repertoire	26	No
34	B/O Sushmitha Nenjundeshwar	M	2.6	30	LSCS	Yes	No	Good	No	37W+3DAYS	Cried after Bag and Mask	5	7	-16	2	None	None	1-Mild	Normal	28	No
35	B/O Komal Gangaram	F	2.7	23	NVD	No	No	Good	Yes	37W	No Cry-Intubated	3	6.76	-25	30	Yes	Yes	3-Severe	Cramped Synchronous	5	Received

36	B/O Manjula Shivanand	M	2.5	25	LSCS	Yes	No	Good	No	38W+2DAYS	Cried after Bag and Mask	5	7	-17	1	None	None	1-Mild	Normal	28	No
37	B/O Renuka Shahapurkar	F	2.6	30	LSCS	Yes	No	Good	No	37W	Cried after Stimulation	5	7.2	-16	3	None	None	1-Mild	Poor Repertoire	28	No
38	B/O Manjula Sangamesh	M	2.5	26	NVD	Yes	Yes	Good	Yes	39W	Cried after prolonged Bag and Mask	5	7	-16	1	None	None	1-Mild	Normal	28	No
39	B/O Laxmi Dhnyaneshwar	M	2.9	29	NVD	No	Yes	Good	Yes	39W	No Cry-Intubated	3	6.8	-26	10	Yes	Yes	2-Moderate	Poor Repertoire	12	Received
40	B/O Savitha Lamani	F	2.6	24	NVD	Yes	No	Poor	No	37W	Cried after prolonged Bag and Mask	5	7	-17	4	None	None	1-Mild	Poor Repertoire	26	No
41	B/O Sanjana Solapure	F	3	29	NVD	No	No	Good	No	38W+3DAYS	Cried after Stimulation	5	6.99	-16	1	None	None	1-Mild	Normal	27	No
42	B/O Shareen Ahmed	M	2.8	30	LSCS	Yes	No	Good	No	37W	Cried after Bag and Mask	5	7.1	-16	2	None	None	1-Mild	Normal	28	No
43	B/O Lavanya Desai	F	3.2	26	NVD	No	No	Good	No	38W+2DAYS	Cried after prolonged Bag and Mask	4	6.8	-19	6	None	None	1-Mild	Poor Repertoire	25	No
44	B/O Gangavva Yellapa	M	3.3	31	NVD	No	Yes	Good	Yes	39W	Cried after prolonged Bag and Mask	4	7	-18	12	None	Yes	2-Moderate	Poor Repertoire	24	No
45	B/O Geetha Basavaraj	M	2.5	25	LSCS	Yes	No	Good	No	37W+4DAYS	Cried after Stimulation	5	7.1	-16	1	None	None	1-Mild	Normal	27	No
46	B/O Hollevva Mahanthesh	F	2.4	28	LSCS	No	Yes	Good	Yes	38W+3DAYS	Cried after prolonged Bag and Mask	4	6.89	-19	4	None	None	1-Mild	Poor Repertoire	26	No
47	B/O Rohini Sadhashiv Patil	F	2.7	27	LSCS	No	No	Good	No	40W	Cried after Bag and Mask	3	7	-16	2	None	None	1-Mild	Normal	28	No
48	B/O Gayathri Shailesh Patil	M	2.8	29	NVD	Yes	No	Good	No	37W+6DAYS	Cried after Stimulation	5	7.1	-17	2	None	None	1-Mild	Normal	28	No
49	B/O Shraddha	F	2.6	24	NVD	No	Yes	Good	Yes	38W+2DAYS	No Cry-Intubated	3	6.7	-24	15	None	Yes	2-Moderate	Poor Repertoire	12	Received
50	B/O Girija Manjunath	M	3.1	30	LSCS	No	No	Good	No	38W+3DAYS	Cried after Stimulation	4	7.04	-18.2	3	None	None	1-Mild	Normal	28	No
51	B/O Ballavva Basappa	F	3.8	22	NVD	No	No	Poor	Yes	38W	Cried after prolonged Bag and Mask	5	7.1	-17	2	None	None	1-Mild	Normal	27	No
52	B/O Vidhya Basavaraj	F	3.4	27	NVD	Yes	No	Poor	No	39W+1 DAY	Cried after Bag and Mask	5	7	-16.5	3	None	None	1-Mild	Normal	28	No
53	B/O Lalitha Ramesh	M	3.2	25	LSCS	No	Yes	Good	Yes	37W+6 DAYS	Cried after Stimulation	5	7.18	-16	2	None	None	1-Mild	Poor Repertoire	26	No
54	B/O Radhika suresh patil	M	2.8	24	NVD	No	No	Good	Yes	39W+3DAYS	Cried after prolonged Bag and Mask	5	6.8	-18	3	None	None	1-Mild	Normal	28	No
55	B/O Sukanya Hanmanth	M	2.5	29	LSCS	Yes	Yes	Good	No	41W	Cried after Bag and Mask	4	6.99	-17.2	2	None	None	1-Mild	Normal	28	No

56	B/O Niranjana Pradeep Patil	F	2.7	31	NVD	No	Yes	Good	Yes	40W+4DAYS	No Cry-Intubated	2	6.8	-19	20	None	Yes	2-Moderate	Poor Repertoire	12	No
57	B/O Bhagrayshree Mallikarjun	M	2.2	28	LSCS	Yes	No	Good	No	37W+1 DAY	Cried after Stimulation	4	7	-16	1	None	None	1-Mild	Normal	28	No
58	B/O Yellavva Doddannavar	F	2.8	25	NVD	No	Yes	Good	Yes	37W+4DAYS	Cried after Bag and Mask	3	7.1	-16	2	None	None	1-Mild	Normal	28	No
59	B/O Ashwini Patil	F	2.5	26	LSCS	No	No	Good	Yes	39W+5 DAYS	Cried after Stimulation	5	7.2	-15.9	1	None	None	1-Mild	Normal	28	No
60	B/O Saritha Hukkeri	M	2.6	29	NVD	No	Yes	Good	No	38W	Cried after prolonged Bag and Mask	4	6.9	-16	2	None	None	1-Mild	Poor Repertoire	24	No