Original Article

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Paediatrics Section

Risk Factors for Deranged Renal Function in Term Asphyxiated Newborn Babies: A Cross-sectional Study

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ABSTRACT

Introduction: Perinatal asphyxia is a significant cause of morbidity and mortality in the Neonatal Intensive Care Unit (NICU). As the kidneys are very sensitive to hypoxia, renal insufficiency can occur within 24 hours of a hypoxic insult and may lead to irreversible injury.

Aim: To evaluate risk factors for impaired renal function in term asphyxiated newborn babies in a tertiary care hospital located in Central India.

Materials and Methods: A cross-sectional observational study was conducted in the Neonatal Intensive Care Unit (NICU), IGGMC and Mayo Hospital, Nagpur, Maharashtra, Central India, from October 2020 to September 2022. A total of 95 term neonates with perinatal asphyxia were enrolled. Risk factors were noted, urine output was recorded, and neonates were classified according to the Kidney Disease Improving Global Outcomes (KDIGO) Acute Kidney Injury Network (AKIN) criteria. Data were tabulated and statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) software version 21.0 to determine the significance of each risk factor for AKI. Continuous variables were compared using the unpaired t-test or Mann-Whitney U Test (when datasets were not normally distributed). Categorical variables were compared using the Chi-square test or Fisher's-exact test.

Results: Out of 95 neonates, comprising 53 males and 42 females with a mean gestational age of 38.6 weeks in the AKI group and 34 weeks in the non AKI group, 58 (61.1%) had AKI; 15 (25.86%) were AKI stage 1, 28 (48.27%) were AKI stage 2, and 15 (25.86%) were AKI stage 3. Among the risk factors, significant perinatal risk factors included Meconium-Stained Liquor (MSL) (p-value=0.0252), oligohydramnios (p-value=0.0246), prolonged labour (p-value=0.0276), and endotracheal tube (ETT) intubation as a mode of resuscitation (p-value=0.0008). Maternal risk factors such as Gestational Diabetes Mellitus (GDM) (p-value=0.0488) and Pregnancy-induced Hypertension (PIH) (p-value=0.0392) were significant. Neonatal shock (p-value=0.001) and Hypoxic-ischaemic Encephalopathy (HIE) (p-value=0.0049) were significant risk factors for AKI in this study.

Conclusion: Perinatal asphyxia is one of the common causes of neonatal mortality, with AKI being the earliest and most common complication as seen in the current study, where 61.1% of neonates with perinatal asphyxia had AKI. By early detection and prevention of risk factors causing AKI in perinatal asphyxia, neonatal mortality can be reduced significantly.

Keywords: Complication, Dysfunction, Hypoxia, Injury, Kidneys, Neonates, Renal insufficiency

INTRODUCTION

Perinatal asphyxia is a common problem in the NICU and a significant cause of morbidity and mortality [1]. The organs most affected by perinatal asphyxia are the kidneys in 50% of cases, followed by the brain in 28%, the Cardiovascular System (CVS) in 25%, and the lungs in 23% [2]. The kidneys are highly sensitive to hypoxia; thus, renal insufficiency can occur within 24 hours of a hypoxic insult and may lead to irreversible injury, if prolonged.

Acute kidney injury is defined as an absolute increase in serum creatinine of more than or equal to 0.3 mg/dL, a percentage increase in serum creatinine of more than or equal to 50% (1.5-fold from baseline), or a reduction in urine output (documented oliguria of less than 1 mL/kg/hr over 24 hours) [3]. According to the KDIGO guidelines, for both the AKIN stage and the Paediatric Risk, Injury, Failure, Loss of kidney function and End-stage kidney disease (pRIFLE) criteria, only one criterion (either serum creatinine rise or urine output decline) needs to be fulfilled [4,5].

Early recognition of AKI is crucial in asphyxiated neonates, as it facilitates timely intervention and appropriate management. There is a scarcity of studies from Central India, as not many have been conducted in this region [6,7]. Therefore, the aim of the present study was to evaluate risk factors for impaired renal function in term asphyxiated newborn babies in a tertiary care hospital located in Central India.

MATERIALS AND METHODS

The present cross-sectional observational study was conducted in the NICU, IGGMC and Mayo Hospital, Nagpur, Maharashtra, Central India, from October 2020 to September 2022. The study received approval from the Institutional Ethics Committee (IEC No. IGGMC/Pharma/BORS/616-17/2021).

Inclusion criteria: Newborns with a gestational age of ≥37 weeks up to 41 6/7 weeks; less than or equal to six hours old; delivered in the present study hospital or outside but recruited within six hours of birth; evidence of perinatal asphyxia as defined by the operational definition, which includes an Appearance, pulse, grimace, activity and respiration (APGAR) score ≤3 at 10 minutes or the continued need for resuscitation with positive pressure ventilation ± chest compressions at 10 minutes of age [4]; and newborns whose guardians provided written informed consent were included in the study.

Exclusion criteria: Parents or guardians who did not consent; gestational age <37 weeks or >42 weeks; age more than six hours; maternal renal abnormalities; sonologically detectable renal anomalies in an Antenatal Care (ANC) scan were excluded from the study.

Sample size calculation: The required sample size was calculated to be 95 using the following formula: $N=z^2pq/d^2$, where p=expected proportion, d= absolute precision= 10% = 0.1, $\alpha/2$= desired confidence level (CI)= 95%, Z1-$\alpha/2$=1.96 at 95% Confidence Interval (CI). The anticipated incidence of AKI in birth asphyxia was p= 44.21%= 0.4421 according to study by Aslam M et al., [7], q= 1-p= 1-0.4421= 0.5579. Thus, $N= 1.96^2x0.4421x0.5579/0.1^2$= 3.84x0.2488/0.01= 94.69, which is approximately 95.

Study Procedure

The present study included 95 sequential term babies from the inborn and outborn sections of the NICU, as evaluated by the New Ballard Score [8] (for consenting parents), with perinatal asphyxia, as per the operational definition of an APGAR score ≤3 at 10 minutes or continued need for resuscitation with positive pressure ventilation ± chest compressions at 10 minutes of age. A detailed history was taken, and a general physical and systemic examination was conducted for each patient. The babies were evaluated for stages of HIE according to the Sarnat and Sarnat stages of HIE [4]. Urine output was recorded daily in terms of mL/kg/hr. Two groups of term babies with perinatal asphyxia were compared: one with deranged renal function and the other without, according to AKIN [4]. The risk factors at enrollment that we proposed to compare included maternal risk factors such as age, parity, diabetes mellitus, hypertension, eclampsia; perinatal risk factors such as mode of delivery, meconium-stained liquor, oligohydramnios, prolonged rupture of membranes, antepartum haemorrhage, prolonged labour, mode and duration of resuscitation; and neonatal risk factors such as gender, gestational age, birth weight, neonatal shock and stages of HIE.

STATISTICAL ANALYSIS

Categorical variables were presented as frequencies and percentages (%), and continuous variables as means±Standard Deviation (SD).. Data were entered into an Microsoft (MS) Excel spreadsheet and analysed using SPSS software version 21.0. Continuous variables were compared using the unpaired t-test or the Mann-Whitney U test when the datasets were not normally distributed. Categorical variables were compared using the Chi-square test or Fisher's-exact test as appropriate. A p-value of <0.05 was considered statistically significant.

RESULTS

Out of the 95 term asphyxiated newborn babies, 58 (61%) had AKI, while 37 (39%) did not. Of the total, 53 (55.8%) were males, and 42 (44.2%) were females. The mean gestational age in AKI cases was 38.6 weeks, compared to 38.4 weeks in non AKI cases. The mean birth weight was 2646.2±380.11 grams for AKI cases and 2719.5±381.41 grams for non AKI cases. The mean APGAR score in AKI cases was 3.98±0.96, while it was 4.45±0.73 in non AKI cases. The mean duration of resuscitation was 95.51±79.18 seconds for AKI cases and 60.13±144.12 seconds for non AKI cases [Table/Fig-1].

Variables	AKI (Mean±SD)	Non AKI (Mean±SD)
Mean gestational age (weeks)	38.6	38.4
Mean birth weight (grams)	2646.2±380.11	2719.5±381.41
Mean APGAR score	3.98±0.96	4.45±0.73
Mean duration of resuscitation (sec)	95.51±79.18	60.13±144.12

[Table/Fig-1]: Comparison between AKI and non AKI groups.

The mean urine output in various stages of AKI was as follows: Stage 1 AKI had mean urine outputs of 0.456, 0.442 and 0.435 mL/kg/hr at 24, 48 and 72 hours, respectively. Stage 2 AKI had mean urine outputs of 0.428, 0.42 and 0.415 mL/kg/hr, and stage 3 AKI had mean urine outputs of 0.242, 0.252 and 0.245 mL/kg/hr at the corresponding time points.

Of the 58 subjects suffering from AKI, 15 (25.86%) were in stage 1, 28 (48.2%) in stage 2 and 15 (25.86%) in stage 3. It was observed that gender and presentation had no significant association with the occurrence of AKI. In contrast, shock and the presence of HIE were statistically significant, with p-values of <0.001 and 0.0049, respectively [Table/Fig-2].

Factors	Total n (%)	Acute Kidney Injury (AKI)		p-value
		Present (N=58) n (%)	Absent (n=37) n (%)	
Gender				
Male	53 (55.8)	36 (67.9)	17 (32.1)	0.1229
Female	42 (44.2)	22 (52.4)	20 (47.6)	
Presentation				
Cephalic	80 (84.2)	48 (60)	32 (40)	0.3135
Others	15 (15.8)	10 (66.7)	5 (33.3)	
Shock				
Yes	37 (38.9)	30 (81.1)	7 (18.9)	**<0.001**
No	58 (61.1)	28 (48.3)	30 (51.7)	
Stages of HIE				
Stage 1	47 (49.5)	22 (46.8)	25 (53.2)	**0.0049**
Stage 2	21 (22.1)	13 (61.9)	8 (38.1)	
Stage 3	27 (28.4)	23 (85.2)	4 (14.8)	

[Table/Fig-2]: Association of neonatal risk factors and AKI. The p-value in bold font indicates statistically significant values

Mode of delivery, PROM and bleeding per vagina had no significant association with the occurrence of AKI. Meconium-stained liquor (MSL), oligohydramnios and prolonged labour were statistically significant, with p-values of 0.0252, 0.0246 and 0.0276, respectively. Regarding the mode of resuscitation, Endotracheal Tube (ETT) intubation was significantly more associated with AKI than bag and mask ventilation (p-value=0.0008) [Table/Fig-3].

Factors	Total n (%)	Acute Kidney Injury (AKI)		p-value
		Present (N=58) n (%)	Absent (n=37) n (%)	
Mode of delivery				
LSCS	49 (51.5)	32 (65.4)	17 (34.6)	0.7333
Vaginal	43 (45.3)	24 (55.8)	19 (44.2)	
Assisted vaginal	3 (3.2)	2 (66.7)	1 (33.4)	
Meconium stained liquor				
Present	20 (21.1)	16 (80)	4 (20)	**0.0252**
Absent	75 (78.9)	42 (56)	33 (44)	
Oligohydramnios				
Present	10 (10.5)	9 (90)	1 (10)	**0.0246**
Absent	85 (89.5)	49 (57.7)	36 (42.3)	
Prolonged rupture of membranes				
Present	6 (6.3)	3 (50)	3 (50)	0.4332
Absent	89 (93.7)	55 (61.8)	34 (38.2)	

Bleeding per vaginum				
Present	5 (5.3)	5 (100)	0	0.079
Absent	90 (94.7)	53 (58.9)	37 (41.1)	
Labour				
Prolonged	11 (11.6)	10 (90.9)	1 (9.1)	**0.0276**
Not prolonged	84 (88.4)	48 (57.2)	36 (42.8)	
Mode of resuscitation				
Endotracheal intubation	29 (30.5)	25 (86.2)	4 (13.8)	**0.0008**
Bag and mask	66 (69.5)	33 (50)	33 (50)	

[Table/Fig-3]: Association of perinatal risk factors and AKI.

Parity showed no association with the occurrence of AKI. However, gestational Diabetes Mellitus (DM) and pregnancy-induced hypertension (PIH) were significantly associated with AKI, with p-values of 0.0488 and 0.0392, respectively [Table/Fig-4].

Factors	Total n (%)	Acute Kidney Injury (AKI)		p-value
		Present (n=58) n (%)	Absent (n=37) n (%)	
Parity				
Primi	65 (68.5)	40 (61.5)	25 (38.4)	**0.8863**
Multi	30 (31.5)	18 (60)	12 (40)	
Gestational DM				
Present	12 (12.6)	10 (83.33)	2 (16.67)	**0.0488**
Absent	83 (87.4)	48 (57.8)	35 (42.16)	
Pregnancy-induced Hypertension (PIH)				
PIH	9 (9.5)	8 (88.88)	1 (11.11)	**0.0392**
No PIH	86 (90.5)	50 (58.13)	36 (41.86)	

[Table/Fig-4]: Association of maternal risk factors and AKI.

The p-value was 0.00523, which was significant, indicating a positive association between the stage of HIE and the stage of AKI [Table/Fig-5]. Therefore, it can be inferred that the more severe the stage of HIE, the more severe the stage of AKI.

Total (n=58)	AKI Stage 1 (n=15) n (%)	AKI Stage 2 (n=28) n (%)	AKI Stage 3 (n=15) n (%)	p-value
HIE 1 (22) (37.9%)	7 (46.6)	14 (50)	1 (6.7)	**0.00523**
HIE 2 (13) (22.5%)	4 (26.7)	8 (28.5)	1 (6.7)	
HIE 3 (27) (39.6%)	4 (26.7)	6 (21.5)	13 (86.6)	

[Table/Fig-5]: Stages of HIE and stages of AKI.

DISCUSSION

A total of 95 neonates who had experienced perinatal asphyxia were analysed. Out of which, 58 (61.1%) developed AKI, while 37 (38.9%) did not. The incidence of AKI following perinatal asphyxia has varied in previous studies: 47% according to Gupta BD et al., 42% by Martin-Ancel A et al., 68% by Aggarwal A et al., 70% by Gluckman PD et al., 17.2% by Nouri S et al., 46.1% by Ikpeme EE et al., and 54.1% by Medani SA et al., [6,9-14]. Medani SA et al., utilised the pRIFLE criteria, while Agrawal G et al., Kirley MJ et al., and Zainab et al., employed the modified KDIGO criteria for diagnosing and classifying AKI [14-17].

In the current study, among the neonates with AKI, 36 (62.1%) were males and 22 (37.9%) were females, resulting in a male-to-female ratio of 1.63:1. This is similar to the ratio observed by Bansal SC et al., in Gujarat, which was 1.69:1, and by Katariya KL and Pandya NK, who reported a male-to-female ratio of 2.46:1 [18,19]. In contrast, international studies, such as the one conducted by Saboute M et al., in Iran, showed a composition of 56% males and 44% females [20]. However, Momtaz H et al., observed that AKI was more common in females (87.8%) than in males (12.2%) [21]. In the present study cohort, among those who did not develop AKI, 17 (45.9%) were males, and 20 (54.1%) were females. The higher incidence of AKI in males may be attributed to a genetic predisposition to perinatal disorders like sepsis and respiratory distress syndrome. The mean gestational age in the neonates with AKI in the current study was 36 weeks. This is slightly lower than the 37.44 weeks reported by Bansal SC et al., [18].

The present study revealed that within the group of neonates with AKI, the modes of delivery were vaginal (24; 41.4%), assisted vaginal (2; 3.4%), and Lower Segment Caesarean Section (LSCS) (32; 55.2%). Similar to our findings, a study by Amardiyanto R et al., in Indonesia found that 43% of deliveries were spontaneous vaginal, 10% assisted vaginal, and 47% cesarean section [22]. This higher rate of caesarean sections could influence foetal outcome [22]. These results contrast with a Sudanese study by Medani SA et al., where 56.7% of asphyxiated babies were delivered by spontaneous vaginal delivery, 16.5% by assisted vaginal delivery, and only 27.1% by caesarean section [14].

In our study, the mean birth weight of neonates suffering from AKI was 2646.2±380.11 grams, while those not affected by AKI had a mean birth weight of 2719.5±381.41 grams. The mean APGAR score at 10 minutes for neonates with AKI was 3.98±0.96, compared to 4.45±0.73 for those without AKI. A total of 58 neonates were diagnosed with AKI; among them, 15 (25.86%) were in AKI stage 1, 28 (48.2%) in AKI stage 2, and 15 (25.86%) in AKI stage 3. Aslam M et al., reported that half of their AKI cases were in stage 3 [7].

In our cohort, among the neonates with AKI, 22 (37.9%) were classified as stage 1 HIE, 13 (22.5%) as stage 2 HIE, and 37 (39.6%) as stage 3 HIE. Similar findings were reported by Medani SA et al., in Sudan, where the most common HIE stage was stage 2, observed in 54.1% of cases [14]. Additionally, a study by Alaro D et al., in Kenya found that stage 2 HIE occurred in 30 out of 60 babies (50%) [23]. In the present study, among neonates with AKI stage 1, 7 (46.6%) had stage 1 HIE, 4 (26.7%) had stage 2 HIE, and 4 (26.7%) had stage 3 HIE. In AKI stage 2, 14 (50%) had stage 1 HIE, 8 (28.5%) had stage 2 HIE, and 6 (21.5%) had stage 3 HIE. In AKI stage 3, 1 (6.7%) had stage 1 HIE, 1 (6.7%) had stage 2 HIE, and 13 (86.6%) had stage 3 HIE.

A study by Saboute M et al., reported that 7.8% (3 cases: 2 patients with HIE Stage 3 and 1 patient with HIE Stage 2) developed AKI. This implies that 33% of patients with stage 3 HIE and 5.2% of patients with stage 2 HIE developed AKI [20]. Alaro D et al., found that the prevalence of AKI was 42.9% in stage 3 HIE and 4.6% in stage 1 HIE [23]. It has been observed that neonates with more severe asphyxia are more likely to experience renal failure [9]. In the present study, this association was statistically analysed using the Chi-square test with Yates correction, yielding a significant p-value of 0.00523. Thus, the authors concluded that the severity of HIE is correlated with the severity of AKI. However, a study by Nouri S et al., showed that two-thirds of newborns with AKI had HIE grade II and one-third had grade III HIE [12]. No renal impairment was

observed in newborns with grade I HIE, and the difference was not statistically significant (p-value=0.13).

In the current study, shock was observed in 22 (37.9%) of the patients with AKI. Among those with AKI stage 1, 7 (46.7%) experienced shock and 53.3% (8) did not. In AKI stage 2, shock was present in 10 (35.7%), while 18 (64.3%) did not experience shock. In AKI stage 3, shock was significantly more common, with 13 (86.7%) experiencing shock and only 2 (13.3%) not experiencing shock. The difference was statistically significant, with a p-value of 0.001. Similar findings were observed in a study by Aslam M et al., in New Delhi, India, where shock was more frequently found in the AKI group (26.19%) compared to those without AKI (11.32%), though the difference was not statistically significant (p-value=0.06) [7]. Moreover, within the AKI group, neonates with shock had more severe stages of AKI compared to those without shock, and this difference was statistically significant (p-value=0.04).

Studying risk factors associated with AKI has revealed many important details. The risk factors considered in the present study include gender, birth weight, gestational age, duration of labour, prolonged rupture of membranes, bleeding per vaginum, mode of resuscitation, shock, stages of HIE, oligohydramnios, meconium stained amniotic fluid, maternal diseases and parity. Among neonatal risk factors, shock and male gender were found to be significant. However, presentation, gestational age and birth weight had no significant association with the occurrence of AKI.

For perinatal risk factors, meconium-stained amniotic fluid, oligohydramnios, prolonged labour and ETT intubation were statistically significant. Conversely, the mode of delivery, prolonged rupture of membranes, and bleeding per vaginum showed no significant association with the occurrence of AKI. In the study by Selewski DT et al., perinatal risk factors associated with neonatal AKI included intubation at birth, low APGAR scores, low cord pH, and asystole [24]. Recently, Bolat F et al., confirmed the association between intubation at birth and AKI in NICU population in Turkey [25]. Prolonged labour (total duration of labour >20 hours) was also found more frequently in the AKI group compared to the non AKI group, with a statistically significant difference (p-value<0.05) in a study conducted by Aslam M et al., in New Delhi [7].

Assessing the association of maternal risk factors with AKI, GDM was seen statistically significant (p-value=0.0488). The incidence of PIH was higher in those with AKI, which was statistically significant (p-value=0.0392). This is in contrast to the study by Aslam M et al., where maternal diseases such as hypertensive disorders of pregnancy and gestational diabetes did not show a significant difference [7]. In the present study, parity showed no association with the occurrence of AKI.

The small sample sizes in most studies have been a major hindrance in identifying associations between neonatal or maternal characteristics and AKI.

Limitation(s)

The limitations of the present study include the use of a functional definition of perinatal asphyxia, as direct measurement of cord blood pH and base deficit was challenging due to resource constraints. For the determination of AKI, urine output was the sole criterion used in accordance with AKIN criteria and KDIGO guidelines, since serial serum creatinine level measurements were not feasible owing to limited resources.

CONCLUSION(S)

Thus, it can be concluded that perinatal asphyxia is a common cause of neonatal mortality, with AKI being the earliest and most frequent complication. Early detection and prevention of risk factors leading to AKI in the context of perinatal asphyxia could significantly reduce neonatal mortality.

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