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Original Research Article

Respiratory outcomes in preterm neonates (<32 weeks): impact of complete, partial, and absent antenatal steroid exposure

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ABSTRACT

Background: Preterm birth is a leading cause of neonatal morbidity and mortality, with respiratory distress syndrome (RDS), bronchopulmonary dysplasia (BPD), and prolonged respiratory support as major complications. While antenatal corticosteroids improve respiratory outcomes, the effects of complete, partial, and absent exposure in infants <32 weeks are inconsistently reported. Aim of the study was to compare respiratory outcomes among preterm neonates <32 weeks based on complete, partial, or no antenatal corticosteroid exposure.
Methods: A prospective observational study conducted in the neonatal intensive care unit (NICU) of Sher-i-Kashmir Institute of Medical Sciences (SKIMS), Srinagar, from January 2021 to June 2025. 185 preterm neonates <32 weeks gestation were included: complete antenatal corticosteroids (ACS) (n=127), partial ACS (n=41), and no ACS (n=17). Outcomes included incidence and severity of RDS, need for surfactant therapy, need for respiratory support, BPD at 36 weeks postmenstrual age, and mortality. Statistical analysis included Chi-square, Kruskal–Wallis, and multivariate logistic regression.
Results: Complete ACS significantly reduced RDS (32.3% versus 46.3% and 58.8%), severe RDS, invasive ventilation, and surfactant use (all $p<0.05$). Median ventilation duration (3 versus 5 versus 7 days) and time to room air (20 versus 30 versus 50 days) were shortest with complete ACS ($p<0.001$). BPD (16.5% versus 22.0% versus 58.8%, $p<0.001$) and mortality (17.3% versus 31.7% versus 52.9%, $p=0.002$) were also lowest. ACS coverage, gestational age, and birth weight independently predicted outcomes.
Conclusions: Complete ACS markedly improves outcomes in preterm infants <32 weeks, underscoring the need for timely administration in high-risk pregnancies.

Keywords: Preterm neonates, Antenatal corticosteroids, Respiratory distress syndrome, Bronchopulmonary dysplasia, Neonatal mortality

INTRODUCTION

Preterm birth continues to be a major global health concern and is a leading contributor to neonatal morbidity and mortality. The worldwide incidence is approximately 10%, with an estimated 15 million preterm births in 2010 and 13.4 million in 2020.[1,2] Respiratory complications such as respiratory distress syndrome (RDS), bronchopulmonary dysplasia (BPD), and the need for prolonged ventilatory or oxygen support remain critical determinants of survival and long-term outcomes in these infants. These complications primarily arise from lung immaturity, surfactant deficiency, and structural underdevelopment.[3,4] Antenatal corticosteroids (ACS) are among the most effective interventions to improve outcomes in preterm neonates. Randomized trials and meta-analyses have consistently shown that ACS reduce the incidence and severity of RDS, decrease the requirement for mechanical ventilation, and lower neonatal mortality.[5] Standard therapy consists of a complete course two doses of

betamethasone or four doses of dexamethasone administered between 24 and 34 weeks of gestation.[6] In practice, however, ACS exposure varies: some mothers receive the full course, others only a partial course due to imminent delivery, while some receive none. Although complete ACS clearly improve neonatal respiratory outcomes, the relative benefits of partial versus no exposure remain less well defined.[7,8] More recent studies have expanded our understanding. A 2025 meta-analysis reported that late-preterm ACS (34–36 + 6 weeks) did not significantly reduce RDS but did lower the need for CPAP and surfactant therapy.[9] While concerns about potential long-term neurodevelopmental risks exist, a recent systematic review found no consistent evidence of harm when high-quality studies were considered.[10] Recognizing these distinctions is essential for optimizing perinatal management and guiding parental counselling. Therefore, the present study aimed to compare respiratory outcomes including RDS, surfactant use, ventilatory support, BPD, and mortality among preterm neonates <32 weeks according to complete, partial, or no antenatal steroid exposure.

Aim

Aim of the study was to compare the effect of complete, partial, and no ACS on respiratory outcomes in preterm neonates less than 32 weeks of gestational age.

Objectives

Objectives of the study were: to compare the incidence of RDS, to evaluate the need for and frequency of surfactant therapy among the three study groups, to assess the need for invasive and non-invasive ventilation across the three groups, to compare the duration of invasive ventilation, non-invasive ventilation, and supplemental oxygen requirement, and to determine the incidence of bronchopulmonary dysplasia (BPD) at 36 weeks' postmenstrual age (PMA).

METHODS

This was a hospital-based observational analytical study conducted in the neonatal intensive care unit (NICU) of Sher-i-Kashmir Institute of Medical Sciences (SKIMS), Soura, Srinagar, from January 2021 to June 2025. All preterm infants <32 weeks' gestational age were screened and those meeting the predefined inclusion criteria were enrolled for the study.

Antenatal details were obtained at admission from maternal records and history. The clinical course, interventions, and complications were documented.

Diagnosis and management of RDS

Preterm neonates developing signs of RDS were diagnosed if at least two of the following criteria (NNPD report, 2002–2003) were present: respiratory rate >60/min, subcostal or intercostal retractions, and expiratory grunt.[9]

Initial management was with continuous positive airway pressure (CPAP). The criteria for initiation of mechanical ventilation (MV) included any of the following: failure of optimal CPAP (>8–9 cm H_2O) or apnea on CPAP PaO_2 <50 mmHg or SpO_2 <89% on FiO_2 ≥0.8 $PaCO_2$ >60 mmHg with pH <7.25.

Apnea or gasping respiration

Surfactant was administered as early rescue therapy, advised for neonates requiring CPAP with FiO_2 ≥40% or for those already on MV. Each neonate was followed until discharge or death.

Data were recorded in a structured master chart and analyzed to compare short-term respiratory outcomes among the study groups.

Inclusion criteria

Patients with gestational age <32 weeks, singleton pregnancy, known antenatal corticosteroid exposure, and admission to NICU within 24 hours of birth were included.

Exclusion criteria

Patients with major congenital anomalies, unknown or uncertain ACS exposure, admission after 24 hours of life, and maternal systemic steroid use for non-obstetric reasons were excluded.

Exposure variables

Complete course

4 doses of dexamethasone given 12 hours apart, with the last dose at least 24 hours before birth.

Partial course

It included any incomplete regimen.

No course

No steroid was given.

Outcomes measured

Outcomes measured included incidence and severity of RDS, requirement for surfactant therapy, requirement and duration of invasive and non-invasive ventilation (CPAP, HFNC), high FiO_2 requirement, duration of supplemental oxygen until sustained room air, and incidence of BPD at 36 weeks PMA in-hospital and respiratory-related mortality.

RESULTS

Among 185 (100%) study sample, 127 (60.5%) had received complete antenatal steroid coverage, 41 (19.5%) had received partial coverage, and 17 (8.1%) had received no antenatal steroids. The incidence of RDS was significantly lower in the complete ASC group (32.3%) compared to partial (46.3%) and no ACS (58.8%) (χ^2=6.11, p=0.047). The incidence of severe RDS also showed a significant difference, being lowest in the complete ACS group (5.5%) and highest in the no ASC group (29.4%) (χ^2=10.83, p=0.004).The requirement of high FiO_2 (>0.8) was significantly reduced in neonates with complete ACS (7.1%) compared to partial (12.2%) and no ACS (29.4%) (χ^2=8.32, p=0.016).The need for invasive ventilation was observed in 20.5% of neonates in the complete ASC group, 31.7% in partial ACS, and 52.9% in no ACS, showing a significant difference (χ^2=9.14, p=0.010). The duration of invasive ventilation also differed significantly, with median values of 3, 5, and 7 days, respectively (H=20.1, p<0.001). The need for non-invasive ventilation was 69.3% in complete ACS, 85.4% in partial ACS, and 94.1% in no ACS (χ^2=7.90, p=0.019). The duration of non-invasive ventilation increased stepwise with decreasing steroid coverage (10–12 days versus 14–20 days versus >18 days; H=18.7, p<0.001).The requirement for surfactant was significantly lower in complete ASC (20.5%) compared to partial (29.3%) and no ACS (52.9%) (χ^2=8.76, p=0.013).The average days to sustain on room air were shortest in the complete ASC group (20 days), longer in partial ACS (30 days), and longest in no ACS (50 days) (H=22.4, p<0.001).The incidence of BPD was significantly reduced in the complete ACS group (16.5%) compared to partial (22.0%) and no ACS (58.8%) (χ^2=15.82, p<0.001). Mortality was also significantly lower in neonates with complete ACS (17.3%) compared to partial (31.7%) and no ACS (52.9%) (χ^2=12.32, p=0.002).

On applying multivariate logistic regression to the study cohort (n=185), antenatal steroid coverage, gestational age, and birth weight emerged as the strongest independent predictors of respiratory outcomes. Compared with complete ACS, both partial ACS (OR 1.8, 95% CI 1.1–3.0, p=0.021) and no ACS (OR 2.5, 95% CI 1.2–5.1, p=0.013) significantly increased the risk of RDS, and similar associations were noted for need for ventilation, surfactant therapy, BPD, and mortality. Lower gestational age (<28 weeks) markedly increased risk (OR 2.1, 95% CI 1.1–3.8, p=0.018), while 30–32 weeks was protective (OR 0.45, 95% CI 0.25–0.82, p=0.009). Very low birth weight (<1000 g) strongly increased risk (OR 3.2, 95% CI 1.5–6.9, p=0.003), whereas birth weight ≥1500 g was protective (OR 0.62, 95% CI 0.35–0.95, p=0.031). The Apgar score <7 at 5 minutes showed a borderline association with RDS (OR 2.0, 95% CI 0.9–4.2, p=0.07) and with other outcomes, but became statistically significant for mortality (p=0.009). PROM/chorioamnionitis also remained borderline (OR 1.8, 95% CI 0.8–4.5, p=0.11). In contrast, sex of the neonate (p=0.28), mode of delivery (p=0.42), maternal diabetes (p=0.58), and maternal hypertension (p=0.36) did not show any significant association with adverse outcomes.

Table 1: Demographic characteristics of patients.

Characteristics	N (%)
Gestational age (weeks)	
<28	19 (10.5)
28-29+6	47 (25.2)
30-32	119 (64.3)
Birth weight (grams)	
<1000	33 (17.6)
1000-1499	51 (27.6)
1500-2499	94 (51.8)
≥2500	07 (3.8)
Gender	
Male	97 (52.4)
Female	88 (47.6)
Mode of delivery	
Cesarean	123 (66.5)
Vaginal	62 (33.5)
Apgar score at 5 minutes	
<7	135 (18.9)
≤7	150 (81.1)
Maternal factors	
Diabetes	18 (9.7)
Hypertension	22 (11.9)
Chorioamnitis/PPROM	13 (7.0)

Table 2: Respiratory support characteristics.

Outcome	Complete ACS n=127 (%)	Partial ACS n=41 (%)	No ACS n=17 (%)	Test statistics	P value
RDS incidence	41 (32.3)	19 (46.3)	10 (58.8)	χ^2=6.11	0.047*
Severe RDS incidence	7 (5.5)	5 (12.2)	5 (29.4)	χ^2=10.83	0.004*
High FiO_2 requirement (>0.8)	9 (7.1)	5 (12.2)	5 (29.4)	χ^2=8.32	0.016*
Need for invasive ventilation	26 (20.5)	13 (31.7)	9 (52.9)	χ^2=9.14	0.010*
Duration of invasive ventilation (days)	3	5	7	H=20.1	<0.001*
Need for NIV	88 (69.3)	35 (85.4)	16 (94.1)	χ^2=7.90	0.019*
Duration of NIV (days)	10–12	14–20	>18	H=18.7	<0.001*
Need for surfactant	26 (20.5)	12 (29.3)	9 (52.9)	χ^2=8.76	0.013*

Continued.

Outcome	Complete ACS n=127 (%)	Partial ACS n=41 (%)	No ACS n=17 (%)	Test statistics	P value
Average days to sustain on room air (days	20	30	50	H=22.4	<0.001*
BPD incidence	21 (16.5)	9 (22.0)	10 (58.8)	χ^2=15.82	<0.001*
Mortality	22 (17.3)	13 (31.7)	9 (52.9)	χ^2=12.32	0.002*

*Statistically significant: p value<0.05

Table 3: Multivariate logistic regression for RDS (n=185).

Predicator (RDS)	OR (95%CI)	P value
Antenatal steroid courage (versus complete ACS)		
Partial ACS	1.8 (1.1-3)	0.021
No ACS	2.5 (1.2-5.1)	0.013
Gestational age (versus 28-29+6 weeks)		
<28	2.1 (1.1–3.8)	0.018
30–32	0.45(0.25–0.82)	0.009
Birth weight (versus 1000-1499 g)		
<1000 g	3.2 (1.5–6.9)	0.003
1500–2499 g	0.62 (0.35–0.95	0.031
≥2500 g	0.40(0.12–0.95)	0.048
Sex, male (versus female)	1.2 (0.8–1.9)	0.28
Mode of delivery, caesarean (versus vaginal)	1.1 (0.7–1.8)	0.42
Agar score at 5 minutes, <7 (versus ≥7)	2.0 (0.9–4.2)	0.07
Maternal diabetes, yes (versus no)	1.3 (0.5–3.2)	0.58
PIH/hypertension, yes (versus no)	1.4 (0.6–3.4)	0.36
PPROM/chorioamnitis, yes (versus no)	1.8 (0.8–4.5)	0.11

Reference groups: Complete ACS, 28–29+6 weeks, 1000–1499 g, female, vaginal delivery, Apgar ≥7, no maternal comorbidities/ infection. OR <1=protective effect.

Table 4: Multivariate logistic regression for need for invasive ventilation and surfactant (n=185).

Predicator	OR (95% CI)	P value	OR (95% CI)	P value
Need for invasive ventilation			**Need for surfactant**	
Antenatal steroid courage (versus complete ACS)				
Partial ACS	1.9 (1.0–3.4)	0.041	1.7 (1.0–3.0)	0.049
No ACS	2.8 (1.3-6.0)	0.008	2.9 (1.4-6.0)	0.004
Gestational age (versus 28-29+6 weeks)				
<28	2.8 (1.4-5.7)	0.004	3.0 (1.4 -6.2)	0.004
30–32	0.55 (0.3-0.98)	0.041	0.50 (0.27-0.91)	0.023
Birth weight (versus 1000-1499 g)				
<1000	3.5 (1.6-7.8)	0.002	3.4(1.5-7.5)	0.003
1500–2499	0.50 (0.28-0.89)	0.029	0.48 (0.25-0.91)	0.031
Sex, male (versus female)	1.1 (0.7-1.8)	0.39	1.2 (0.7-2.1)	0.39
Mode of delivery, caesarean (versus vaginal)	1.0 (0.6-1.6)	0.95	1.1 (0.6-1.9)	0.74
Agar score at 5 minutes, <7 (versus ≥7)	2.3 (1.0-4.9)	0.051	1.8 (0.9-3.8)	0.081
Maternal diabetes, yes (versus no)	1.2 (0.5-2.9)	0.65	1.2 (0.4-3.1)	0.65
PIH/hypertension, yes (versus no)	1.3 (0.5 -3.2)	0.61	1.3 (0.5-3.3)	0.57
PPROM/chorioamnitis, yes (versus no)	1.7 (0.7-4.1)	0.12	1.6 (0.7-4.0)	0.15

Reference groups: Complete ACS, 28–29+6 weeks, 1000–1499 g, female, vaginal delivery, Apgar ≥7, no maternal comorbidities/ infection. OR <1=protective effect

Table 5: Multivariate logistic regression for BPD incidence and mortality (n=185).

Predicator	OR (95% CI)	P value	OR (95% CI)	P value
BPD			Mortality	
Antenatal steroid courage (versus complete ACS)				
Partial ACS	2.0 (1.1-3.8)	0.024	2.4 (1.2-5.0)	0.015

Continued.

Predicator	OR (95% CI)	P value	OR (95% CI)	P value
No ACS	3.5 (1.6-7.8)	0.002	4.5 (2.0-10.1)	<0.001
Gestational age (versus 28-29+6 weeks)				
<28	4.2 (1.9-9.6)	<0.001	5.5 (2.2-13.4)	<0.001
30–32	0.40 (0.2-0.75)	0.006	0.35 (0.15-0.72)	0.004
Birth weight (versus 1000-1499 g)				
<1000	3.8 (1.7-8.2)	0.001	4.8 (2.0-11.0)	<0.001
1500–2499	0.46 (0.24-0.88)	0.031	0.55 (0.28-0.97)	0.032
Sex, male (versus female)	1.2 (0.7-2.1)	0.39	1.1 (0.6-2.0)	0.58
Mode of delivery, cesarean (versus vaginal)	1.0 (0.6-1.8)	0.95	1.0 (0.6-1.7)	0.98
Agar score at 5 minutes, <7 (versus ≥7)	2.2 (1.0-4.9)	0.052	3.0 (1.3-6.8)	0.009
Maternal diabetes, yes (versus no)	1.3 (0.5-3.4)	0.58	1.2 (0.4-0.33)	0.69
PIH/hypertension, yes (versus no)	1.3 (0.5-3.4)	0.61	1.4 (0.6-3.6)	0.48
PPROM/chorioamnitis, yes (versus no)	1.8 (0.7-4.5)	0.13	1.9 (0.8-4.7	0.12

Reference groups: Complete ACS, 28–29+6 weeks, 1000–1499 g, female, vaginal delivery, Apgar ≥7, no maternal comorbidities/infection. OR <1=protective effect

DISCUSSION

In this prospective cohort of 185 preterm neonates, we found that complete ACS coverage, higher gestational age, and greater birth weight were protective against RDS, invasive ventilatory support, surfactant use, BPD, and mortality. Our findings are consistent with the Cochrane review by Roberts et al, which showed that a complete ACS course reduces RDS and neonatal death, and with the World Health Organization guideline regarding use of antenatal steroids.[10,11] The dose–response effect was evident, with partial ACS conferring only intermediate benefit, in line with the overview by Sultana et al and the analysis by Socha et al confirming that timing and completeness critically determine neonatal respiratory outcomes.[10,12] Our RDS incidence of 37.8% lies within the reported range of 30–60% for neonates at 28–32 weeks gestation, similar to previous studies.[13,14] Birth weight showed a similar gradient: neonates <1000 g had nearly threefold higher risk of RDS and related outcomes, while those ≥1500 g had lesser incidence, consistent with findings in previous studies.[15] The need for invasive ventilation and surfactant therapy was lower in those with complete ACS, similar to previous studies and the mechanistic review by Jobe and Goldenberg, which describe ACS-enhanced surfactant production.[16,17] Our BPD incidence of 21.6% is comparable to the 11-50% range reported by study by Yang et al and large observational cohorts including Moreira et al, while our mortality rate of 23.8% is higher than high-income country cohorts but consistent with tertiary-level low- and middle-income country reports such as Manuck et al and Bulimba et al (2022).[18-21] Among covariates, an Apgar score <7 at 5 minutes showed borderline association with respiratory outcomes but was significantly linked to mortality, confirming its prognostic value, while premature rupture of membranes and chorioamnionitis also trended toward borderline significance, consistent with the study conducted by Been et al.[22] Other maternal and neonatal factors such as sex, mode of delivery, diabetes, and hypertension were not significant, in agreement with previous studies who found these variables diminish once GA, BW, and ACS are controlled for.[23,24] Together, these findings emphasize that ensuring complete ACS courses, particularly for lower GA and lower BW infants, remains a cornerstone of neonatal respiratory care and survival improvement.

Limitations

The findings of this study should be interpreted in light of certain limitations. First, this was a single-center study, which may limit the generalizability of the results. Second, the observational design precludes establishing causality. Third, the relatively small number of neonates in the no-ACS group reduced statistical power for subgroup analyses. Finally, long-term outcomes such as neurodevelopmental follow-up were not assessed and remain important areas for future research.

CONCLUSION

Complete antenatal corticosteroid coverage significantly reduced the incidence and severity of respiratory distress syndrome, need for surfactant therapy, invasive ventilation, bronchopulmonary dysplasia, and mortality in preterm neonates <32 weeks of gestation. Partial ACS exposure conferred only intermediate benefit, while absence of exposure was associated with the worst outcomes. Timely and complete administration of ACS should remain a cornerstone of perinatal care in high-risk pregnancies.

Recommendations

Our findings emphasize the importance of ensuring that eligible mothers receive a full course of antenatal corticosteroids prior to preterm delivery. Health systems should strengthen protocols for early identification and timely management of women at risk of preterm birth to avoid missed or incomplete courses. Future multicenter studies with larger cohorts, as well as follow-up into

childhood, are warranted to evaluate long-term respiratory and neurodevelopmental outcomes.

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