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Impact of Small-for-Gestational-Age Severity on Mortality and Morbidity in Very Preterm Infants

Yasemin Ezgi Kostekci,[1] Emel Okulu,[1] Ferhan Demirtas,[1] Akif Kavgaci,[2] Dogan Kaymaz,[1] Gulsah Aynaoglu Yildiz,[3] Omer Erdeve,[1] Begum Atasay,[1] Saadet Arsan[1]

Abstract

Aim: The aim of this study was to investigate the impact of the severity of small-for-gestational-age status on mortality and prematurity-related morbidities in very preterm infants.

Study Design: Data from all inborn very preterm infants (<32 weeks' gestation) were evaluated. Infants with congenital anomalies or those who were large-for-gestational-age were excluded.

Results: Of the 461 infants included, 74 (16%) were classified as small for gestational age (SGA). The rates of culture-proven late-onset sepsis and mortality were higher in the SGA group than in the non-SGA group (p<0.05). However, no significant differences were observed in other prematurity-related morbidities between the groups (p>0.05). The Z-score cut-off value for predicting mortality was –1.68, with a sensitivity of 71.4% and a specificity of 66.7% (area under the curve: 0.696; 95% confidence interval: 0.574–0.819; p=0.005).

Conclusions: SGA infants had higher rates of sepsis and mortality than non-SGA infants. Furthermore, among SGA preterm infants, a lower birth weight Z-score was associated with increased mortality. Careful perinatal follow-up is essential for preterm infants born SGA.

Keywords: Intrauterine growth restriction; Preterm; Small for gestational age; Z-score.

[1]*Division of Neonatology, Department of Pediatrics, Ankara University Faculty of Medicine, Ankara, Türkiye*

[2]*Department of Pediatrics, Ankara University Faculty of Medicine, Ankara, Türkiye*

[3]*Division of Perinatology, Department of Obstetrics and Gynecology, Ankara University Faculty of Medicine, Ankara, Türkiye*

Address for correspondence:
Yasemin Ezgi Köstekci, Division of Neonatology, Department of Pediatrics, Ankara University Faculty of Medicine, Ankara, Türkiye.
E-mail: ezgikostekci@gmail.com

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Introduction

Intrauterine growth restriction (IUGR) is associated with a significantly increased risk of perinatal morbidity and mortality, as well as adverse long-term health outcomes in infants.[1] Fetal growth is influenced by a variety of factors, including uteroplacental function, maternal health, cardiovascular disease, altitude, maternal nutrition, tobacco and substance use, and pathological conditions such as infections and certain genetic abnormalities.[2] In an otherwise healthy fetus, uteroplacental insufficiency is the most common cause of impaired fetal growth.[2] A fetus is classified as small for gestational age (SGA) when its size, determined by biometric assessment, falls below a specific threshold for its gestational age (GA). An estimated fetal weight (EFW) or abdominal circumference (AC) below the 10th percentile is the most commonly used criterion for SGA. Other proposed thresholds include

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the 3rd or 5th percentile or a Z-score below –2.[2] The risks of stillbirth and perinatal death increase in fetuses with birth weights below the 10th percentile, with the highest risk observed among those with birth weights below the 3rd percentile.[3, 4]

Intrauterine growth restriction is a major cause of preterm birth.[5] Both fetal growth restriction and preterm delivery are associated with an increased risk of neonatal mortality and morbidity. Additionally, SGA infants are at greater risk of morbidity and mortality during the first year of life compared with appropriately grown infants, particularly when born preterm.[6]

This study aimed to evaluate the association between SGA and prematurity-related mortality and morbidities in infants born before 32 weeks of gestation.

Materials and Methods

This retrospective study analyzed preterm infants born between January 2014 and July 2022 with GAs ranging from $23^{0/7}$ to $31^{6/7}$ weeks. GA was determined using the first day of the last menstrual period and confirmed by first-trimester ultrasonography. Infants with congenital anomalies, those born outside our center, or those classified as large for gestational age were excluded (Fig. 1). The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Owing to the retrospective study design, the requirement for informed consent was waived by the Ethics Committee.

Neonatal data included GA, birth weight, sex, mode of delivery, antenatal corticosteroid exposure, conception by assisted reproductive technology, abnormal Doppler findings, multiple pregnancy, and 1- and 5-minute Apgar scores. Neonatal outcomes, including respiratory distress syndrome (RDS),[7] intraventricular hemorrhage (IVH),[8] patent ductus arteriosus (PDA),[9] necrotizing enterocolitis (NEC),[10] retinopathy of prematurity (ROP),[11] bronchopulmonary dysplasia (BPD),[12] duration of hospitalization, and mortality, were extracted from hospital medical records. An available-case analysis was per-

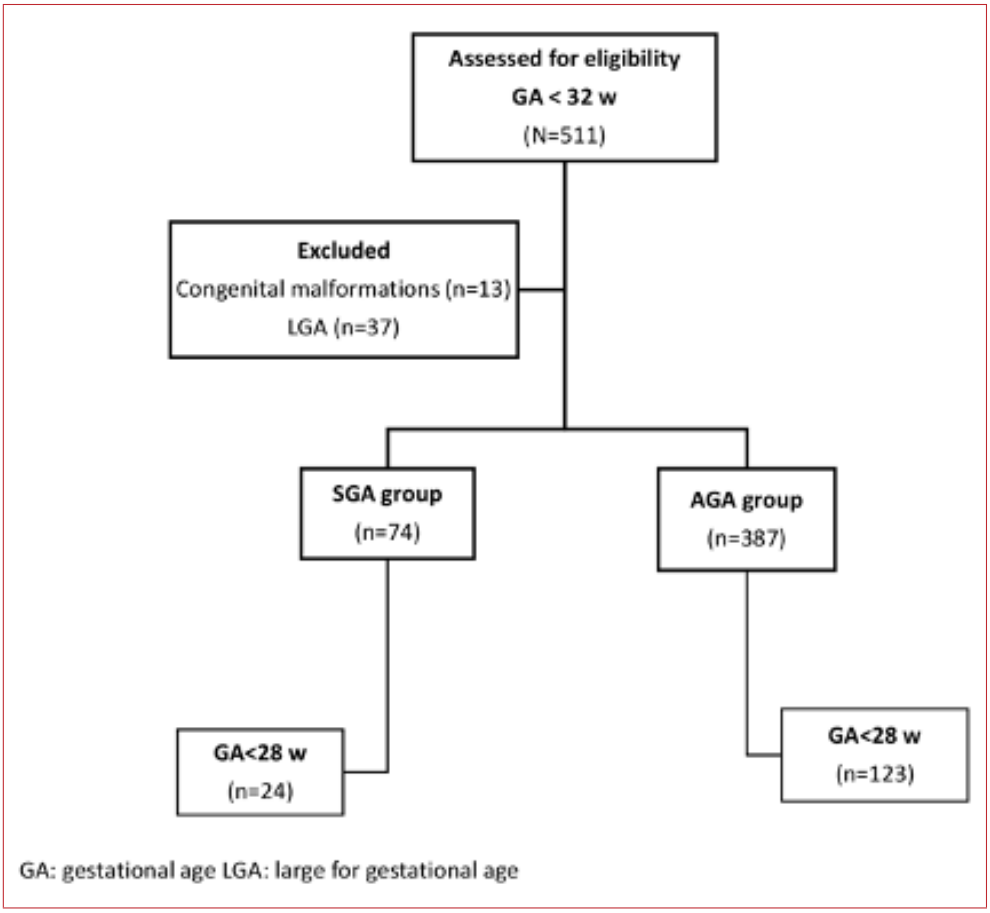


Figure 1. Flowchart of participant selection.

formed for morbidity outcomes. Infants who died before undergoing the relevant diagnostic evaluation (e.g., cranial ultrasonography, echocardiography, or ophthalmologic examination) were excluded from the denominator for that specific outcome. IVH and hemodynamically significant patent ductus arteriosus (hsPDA) analyses included only infants who underwent at least one cranial ultrasound and echocardiographic examination, respectively. ROP analyses included only infants who received at least one ophthalmologic examination. BPD analyses included infants who survived to 36 weeks' postmenstrual age and were evaluated for BPD at that time.

Small for gestational age was defined as a birth weight below the 10th percentile for GA and sex according to the Fenton growth charts.[13] The infants were divided into two groups according to birth weight for gestational age. The primary outcome was mortality before discharge from the neonatal intensive care unit (NICU). Secondary outcomes included prematurity-related morbidities.

Categorical variables are presented as frequencies and percentages (n, %). Associations between categorical variables were assessed using Pearson's chi-square test when its assumptions were met; otherwise, Fisher's exact test was used. Continuous variables that did not meet the assumptions for parametric analysis were compared using the Mann–Whitney U test. The distribution of numerical data was assessed using the Kolmogorov–Smirnov test, and homogeneity of variances was assessed using Levene's test. Descriptive statistics for continuous variables are presented as mean ± standard deviation. Statistical analyses were performed using IBM SPSS Statistics for Windows, version 25.0 (IBM Corp., Armonk, NY, USA).

Results

A total of 511 infants who met the eligibility criteria were born at our center between January 2014 and July 2022. After applying the exclusion criteria, 461 infants were included in the study cohort. Of these, 74 (16%) were classified as SGA according to the Fenton growth charts. Table 1 summarizes the neonatal anthropometric, prenatal, and perinatal characteristics according to SGA status. As expected, the SGA group had significantly lower mean birth weight and birth weight Z-scores than the appropriate-for-gestational-age (AGA) group (p<0.001). Sex distribution, gestational age at delivery, and the proportion of infants born before 28 weeks' gestation were comparable between the groups. Antenatal steroid exposure was also similar (p=0.255). However, abnormal antenatal Doppler findings and indicated emergency delivery were more common in the SGA group (both p<0.001). Additionally, median 1- and 5-minute Apgar scores were lower in the SGA group (p=0.010 and p=0.036, respectively).

Table 1. Neonatal anthropometric, prenatal, and perinatal characteristics of the study population*

	SGA (n=74)	AGA (n=387)	p
Neonatal anthropometrics			
Birth weight (g)	741 (±212)	1202 (±336)	**<0.001**
Birth weight percentile	5.02 (±2.73)	48.86 (±23.03)	**<0.001**
Birth weight Z-score	-1.71 (±0.31)	-0.01 (±0.74)	**<0.001**
Prenatal and perinatal characteristics			
Gestational age (weeks)	28.64 (±2.08)	28.78 (±2.14)	0.543
Gestational age <28 weeks	24 (32.9)	123 (31.7)	0.843
Male sex	29 (39.7)	173 (44.6)	0.442
Antenatal steroid exposure	54 (74)	310 (79.9)	0.255
Conception by assisted reproductive technology	8 (11.0)	93 (24.0)	**0.014**
Abnormal antenatal Doppler findings	33 (45.2)	24 (6.2)	**<0.001**
Indicated delivery	62 (84.9)	119 (30.7)	**<0.001**
Cesarean delivery	67 (91.8)	320 (82.5)	**0.047**
1-minute Apgar score	5 (1–8)	6 (0–9)	**0.010**
5-minute Apgar score	7 (3–10)	8 (1–10)	**0.036**
Multiple pregnancy	17 (23.3)	165 (42.5)	**0.002**

*Mann–Whitney U and Pearson's chi-square tests were used.

Table 2 presents prematurity-related morbidities and mortality according to SGA status. The frequencies of RDS, hsPDA, NEC, BPD, moderate-to-severe BPD, and ROP did not differ significantly between the SGA and AGA groups, including the subgroup of infants born before 28 weeks' gestation. Similarly, the frequencies of IVH of any grade and severe IVH (grade ≥3) were comparable between the groups. However, among infants born before 28 weeks' gestation, both IVH of any grade and severe IVH occurred more frequently in the AGA group. Culture-proven late-onset sepsis (LOS) was more common in SGA infants (p=0.016), whereas LOS rates were similar between groups among infants born before 28 weeks' gestation. Logistic regression analysis showed that SGA was associated with an increased risk of cul-

Table 2. Prematurity-related morbidities and mortality*

	SGA (n=74)	AGA (n=387)	p
RDS	36 (49.3)	170 (43.8)	0.386
GA <28 weeks	20 (83.3)	86 (69.9)	0.180
IVH (any grade)[a]	14 (21.5)	92 (24.9)	0.565
GA <28 weeks	3 (16.7)	50 (46.7)	**0.017**
IVH (grade ≥3)[a]	3 (4.6)	31 (8.4)	0.297
GA <28 weeks	0 (0.0)	21 (19.6)	**0.039**
hsPDA[b]	11 (18.3)	87 (23.6)	0.370
GA <28 weeks	6 (42.9)	50 (47.2)	0.761
NEC (any stage)	13 (17.8)	67 (17.3)	0.911
GA <28 weeks	5 (20.8)	35 (28.5)	0.443
BPD (any grade)[c]	12 (26.7)	87 (26.4)	0.975
GA <28 weeks	4 (66.7)	57 (70.4)	0.584
Moderate-to-severe BPD[c]	11 (24.4)	45 (13.7)	**0.058**
GA <28 weeks	4 (66.7)	28 (34.6)	0.129
Culture-proven late-onset sepsis	26 (35.6)	87 (22.4)	**0.016**
GA <28 weeks	8 (33.8)	41 (33.8)	>0.99
ROP (any stage)[d]	4 (8.5)	39 (11.6)	0.529
GA <28 weeks	3 (42.9)	26 (30.6)	0.386
ROP requiring treatment[d]	4 (8.5)	12 (3.6)	0.113
GA <28 weeks	3 (42.9)	10 (11.8)	**0.056**
Duration of hospitalization	37.68 (±34.66)	37.27 (±25.62)	0.55
GA <28 weeks	31.29 (±49.26)	50.24 (±35.60)	**0.005**
Mortality	28 (38.4)	59 (15.2)	**<0.001**
GA <28 weeks	18 (75.0)	40 (32.5)	**<0.001**

*Mann–Whitney U and Pearson's chi-square tests were used. [a]Analyzed in infants who underwent at least one cranial ultrasonographic examination. [b]Analyzed in infants who underwent at least one echocardiographic examination. [c]Analyzed for infants who reached 36 weeks' postmenstrual age or were discharged from the NICU. [d]Analyzed in infants who underwent at least one ophthalmologic examination for ROP. BPD: Bronchopulmonary dysplasia; GA: Gestational age; hsPDA: Hemodynamically significant patent ductus arteriosus; IVH: Intraventricular hemorrhage; NEC: Necrotizing enterocolitis; RDS: Respiratory distress syndrome; ROP: Retinopathy of prematurity.

ture-proven LOS (odds ratio [OR]: 1.914; 95% confidence interval [CI]: 1.121–3.268; p=0.017) (Table 3). After adjustment for GA, sex, and antenatal steroid exposure, the OR was 1.985 (95% CI: 1.142–3.449; p=0.015) (Table 3). The duration of hospitalization was similar between groups. Although the incidence of moderate-to-severe BPD was twice as high in SGA infants, the difference was not statistically significant. After adjustment for gestational age, sex, and antenatal steroid exposure, SGA was associated with a 3.8-fold increased risk of moderate-to-severe BPD (OR: 3.841; 95% CI: 1.602–9.206; p=0.003). Mortality was higher in the SGA group (Table 2), with an OR of 3.470 (95% CI: 2.008–5.997; p<0.001) and an adjusted OR of 4.664 (95% CI: 2.431–8.948; p<0.001) (Table 3).

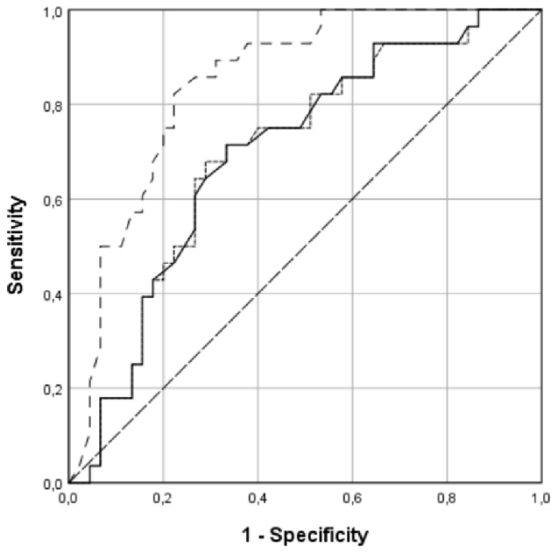
Among SGA infants, receiver operating characteristic (ROC) curve analysis demonstrated that both birth weight Z-score and birth weight percentile significantly predicted mortality (Fig. 2). The Z-score cut-off was –1.68 (area under the curve [AUC]: 0.696; 95% CI: 0.574–0.819; p=0.005), with a sensitivity of 71.4% and a specificity of 66.7%. The corresponding birth weight percentile cut-off was 4.54 (AUC: 0.697; 95% CI: 0.574–0.819; p=0.005), with the same sensitivity and specificity. A birth weight cut-off of 692 g provided the best predictive performance for mortality, with a sensitivity of 82.1%, a specificity of 77.8%, and an AUC of 0.847 (95% CI: 0.759–0.936; p<0.001).

Table 4 presents mortality and morbidity among SGA infants stratified by birth weight percentile (<4.5 vs. 4.5–10). Infants with birth weight percentiles below 4.5 had a 3.2-fold higher risk of RDS (OR: 3.286; 95% CI: 1.258–8.581; p=0.015) and a fivefold higher risk of mortality (OR: 5.00; 95% CI: 1.789–13.975; p=0.002). The frequencies of culture-proven LOS, IVH, and BPD were similar between the two subgroups.

Table 3. Association between SGA status and neonatal morbidities and mortality

	Crude OR	95% CI	p	Adjusted OR*	95% CI	p
Culture-proven LOS	**1.914**	**1.121–3.268**	**0.017**	**1.985**	**1.142–3.449**	**0.015**
IVH (any grade)	0.829	0.439–1.568	0.565	0.808	0.415–1.575	0.531
IVH (grade ≥3)	0.529	0.157–1.784	0.305	0.492	0.139–1.750	0.274
BPD (any grade)	1.011	0.500–2.046	0.975	1.647	0.693–3.916	0.259
Moderate-to-severe BPD	2.042	0.965–4.319	0.062	**3.841**	**1.602–9.206**	**0.003**
Mortality	**3.470**	**2.008–5.997**	**<0.001**	**4.664**	**2.431–8.948**	**<0.001**

BPD: Bronchopulmonary dysplasia; CI: Confidence interval; LOS: Late-onset sepsis; IVH: Intraventricular hemorrhage; OR: Odds ratio. *ORs were adjusted for gestational age, sex, and antenatal corticosteroid exposure.



	Cut-off	p value	Sensitivity	Specificity	AUC (95 % CI)
BW	692	<0.001	%82.1	%77.8	0.847 (0.759-0.936)
BW – Z-score	-1.68	0.005	%71.4	%66.7	0.696 (0.574-0.819)
BW - percentile	4.54	0.005	%71.4	%66.7	0.697 (0.574-0.819)

AUC: area under curve, BW: birth weight, CI: confidence interval

Figure 1. Receiver operating characteristic (ROC) curves for birth weight, birth weight Z-score, and birth weight percentile for predicting mortality in small-for-gestational-age (SGA) preterm infants.

Discussion

This study demonstrated that preterm infants with SGA had higher risks of mortality and LOS than AGA infants. Most prematurity-related morbidities were comparable between the two groups. However, among infants born before 28 weeks' gestation, AGA infants had higher rates of IVH than SGA infants. Additionally, moderate-to-severe BPD was more frequent in the SGA group. Mortality occurred predominantly among infants with birth weight percentiles below 4.5 and birth weight Z-scores below –1.68. It should be noted that the ROC-derived

Table 4. Mortality and prematurity-related morbidities according to birth weight percentile among SGA infants

		n	%	Crude OR	95% CI	p
RDS	<4.5th percentile	23	65.7	**3.286**	1.258–8.581	**0.015**
	4.5th–10th percentile	14	36.8			
Culture-proven LOS	<4.5th percentile	14	40.0	1.444	0.552–3.779	0.454
	4.5th–10th percentile	12	31.6			
IVH (any grade)	<4.5th percentile	8	26.7	1.758	0.532–5.805	0.355
	4.5th–10th percentile	6	17.1			
BPD (any grade)	<4.5th percentile	6	40	2.667	0.680–10.458	0.159
	4.5th–10th percentile	6	20			
Moderate-to-severe BPD	<4.5th percentile	6	40	3.333	0.814–13.658	0.094
	44.5th–10th percentile	5	16.7			
Mortality	<4.5th percentile	20	**57.1**	**5.000**	**1.789–13.975**	**0.002**
	4.5th–10th percentile	8	21.1			

BPD: Bronchopulmonary dysplasia; CI: Confidence interval; LOS: Late-onset sepsis; IVH: Intraventricular hemorrhage; OR: Odds ratio; RDS: Respiratory distress syndrome.

cut-off values showed only moderate discriminative ability (AUC: 0.69). These thresholds lack external validation and should be considered exploratory findings rather than validated clinical predictors.

Survival rates among preterm SGA infants vary across centers. Chalubinski et al.[14] reported an 87.9% survival rate in neonates with IUGR, while Brodszki et al.[15] reported a survival rate of 89%. In our study, the survival rate among SGA infants was 61.6%, which is comparable to the 69% reported by Baschat et al. [16] Chalubinski et al.[14] also demonstrated that neonatal mortality increased when the Z-score was below –1.96 in growth-restricted infants. Most published studies have similarly reported an association between SGA status and increased mortality.[17, 18] In contrast, one prospective cohort study found no significant difference in mortality,[19] although the infants included in that study had a higher gestational age than those in our cohort. Nevertheless, similar mortality rates have been reported among infants born at earlier gestational ages. Brodszki et al.[15] reported similar mortality and neonatal morbidity rates in infants with IUGR and non-IUGR controls born before 30 weeks' gestation.

Prematurity-related morbidities may also vary according to gestational age. Engineer et al.[18] reported increased risks of RDS, neonatal sepsis, and NEC in infants with IUGR, with higher mortality primarily attributed to sepsis and respiratory failure. Silva et al.[20] found higher rates of nosocomial sepsis, ROP, and BPD in IUGR infants, whereas IVH, PDA, and NEC occurred at similar rates in IUGR and non-IUGR infants. Likewise, a retrospective case-control study demonstrated a higher prevalence of LOS among SGA and IUGR neonates.[20] Consistent with these findings, SGA infants in our cohort had higher rates of LOS than AGA infants. This increased risk may be related to delayed enteral feeding, prolonged central venous catheter use, extended dependence on total parenteral nutrition. Furthermore, reduced transplacental transfer of maternal immunoglobulins and bone marrow suppression may also increase the risk of sepsis. However, our study did not find a statistically significant difference in LOS rates among infants born before 28 weeks' gestation. This finding may be explained by the inherently high incidence of sepsis in extremely preterm neonates, regardless of whether they are appropriate for gestational age or small for gestational age.

Zeitlin et al.[17] demonstrated a strong association between lower birth weight percentiles and increased risks of mortality and BPD. Similarly, Brodszki et al.[15] reported a greater need for supplemental oxygen at 36 weeks' postmenstrual age among infants with IUGR. This finding was observed in fetuses with IUGR and abnormal fetal blood flow and was associated with the subsequent development of chronic lung disease. In our study, the overall incidence of BPD was similar between SGA and AGA infants. However, moderate-to-severe BPD was more common in the SGA group. After adjustment for GA, sex, and antenatal steroid exposure, SGA was associated with a 3.8-fold increased risk of moderate-to-severe BPD.

Neither Zeitlin et al.[17] nor the present study identified an association between birth weight percentile and IVH risk in preterm infants. Interestingly, among infants born before 28 weeks' gestation, AGA infants had higher rates of both any-grade IVH and severe IVH than SGA infants.

The findings of this study are generally consistent with those reported in the literature. However, the major limitation of this study was its retrospective design, which limited the availability of important clinical data, including antenatal Doppler findings. Another limitation of our regression model is the lack of adjustment for certain baseline characteristics, such as multiple pregnancy and conception by assisted reproductive technology, which requires cautious interpretation of the reported odds ratios. However, adjustment for intermediate clinical variables, such as abnormal Doppler findings and indicated delivery, was intentionally avoided to prevent overadjustment bias because these variables are intrinsically linked to the pathophysiology of severe SGA status. Another limitation is the small sample size in certain subgroup analyses (e.g., SGA infants born before 28 weeks' gestation and birth weight percentile subgroups), which limits statistical power and requires cautious interpretation of these findings.

The definition of SGA in this study was based solely on birth weight percentiles in accordance with current clinical practice. Additionally, BPD was evaluated only in infants who survived to 36 weeks' postmenstrual age, introducing the potential for survival bias because mortality was higher among SGA infants. Consequently, severe respiratory morbidity may have been underestimated in this group. Furthermore, because the study period extended over nearly a decade, gradual changes in NICU practices, including respiratory management and nutritional strategies, may have influenced the incidence of some neonatal morbidities, representing anoth-

er limitation of this retrospective cohort. Despite these limitations, the study has several strengths, including its conduct at a tertiary referral neonatal intensive care center and the inclusion of a relatively large cohort of 461 inborn very preterm infants. Moreover, unlike many previous studies that included infants born up to 36 weeks' gestation, our cohort was limited to infants born before 32 weeks' gestation.

There is currently no universally accepted definition of SGA status in relation to clinical outcomes in preterm infants. Severe SGA is generally defined as a birth weight below the 3rd percentile; however, the thresholds associated with neonatal morbidity and mortality vary among studies and NICUs. Although international frameworks traditionally define severe growth restriction using the 3rd percentile or a Z-score below -2, our ROC analysis identified a statistical cut-off of 4.54. Because this threshold is specific to our study population, it should be interpreted cautiously as an exploratory finding rather than a replacement for established clinical definitions. Close collaboration between obstetricians and neonatologists is essential to optimize clinical management and improve neonatal outcomes.

Conclusion

Early identification, careful monitoring, and timely delivery of SGA infants are essential for improving both short- and long-term neonatal outcomes. Appropriate postnatal follow-up of infants with SGA may reduce prematurity-related morbidities.

Ethics Committee Approval: Ethics committee approval was obtained from Ankara University Faculty of Medicine Human Research Ethics Committee (Approval Number: I11-1028-25, Date: 06.01.2026).

Informed Consent: The requirement for informed consent was waived by the Ethics Committee due to the retrospective nature of this study.

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