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ORIGINAL RESEARCH
Newborn

The reliability of Ponderal Index in predicting short-term complications of small for gestational age term infants

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ABSTRACT

Objective: The birth weight (BW) for gestational age (GA) provides an accurate assessment of the nutritional status of small for gestational age (SGA) infants. The ponderal index (PI) is used to identify wasting. In this study, we aimed to evaluate the association between PI values and short-term complications of term SGA infants and assess the reliability of PI.

Material and Methods: A total of 489 term SGA infants were enrolled in this retrospective study. Group 1 comprised infants with low PI (PI<10th percentile) (n=45), while groups 2 and 3 consisted of infants with appropriate PI (PI 10th–90th percentile) (n=405) and high PI (PI>90th percentile) (n=39), respectively. Demographic and clinical data of the mothers and neonates were collected and compared statistically.

Results: No difference was observed between the groups, except for the incidence of hypoglycemia, jaundice requiring treatment, and hospitalization rate, which were all significantly higher in the low PI group compared to groups 2 and 3 (p=0.01, p=0.006, and p=0.04, respectively).

Conclusion: Although short-term complications were higher in term SGA infants with low PI, all term SGA infants should be defined as high-risk neonates and warrant special neonatal care and surveillance to prevent short-term complications.

Keywords: Morbidity; ponderal index; SGA; short-term complication; term infant.

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Gestasyon yaşına göre düşük doğum ağırlıklı term bebeklerin kısa dönem komplikasyonlarını öngörmede Ponderal indeksin güvenilirliği

ÖZET

Amaç: Gebelik yaşına göre doğum ağırlığı, SGA bebeklerin beslenme durumunun adil bir şekilde değerlendirilmesini sağlar. Ponderal indeks, "wasting"i (yaşa göre boy oranı normalken kilo kaybı ve akut beslenme yetersizliği) tanımlamak için kullanılır. Bu çalışmada, term SGA bebeklerin PI değerleri ile kısa dönem komplikasyonlar arasındaki ilişkiyi ve PI'in güvenilirliğini değerlendirmeyi amaçladık.

Gereç ve Yöntemler: Bu retrospektif çalışmaya toplam 489 term SGA bebek dahil edildi. Grup 1, düşük PI (PI<10. persentil) (n=45) olan bebeklerden oluşurken, grup 2 ve 3, uygun PI (PI 10.-90. persentil) (n=405) ve yüksek PI (PI>90. persentil) (n=39) olan bebeklerden oluşmuştur. Anne ve yenidoğanların demografik ve klinik verileri toplanıp istatistiksel olarak karşılaştırılmıştır.

Bulgular: Düşük PI grubunda, hipoglisemi insidansı, tedavi gerektiren sarılık ve hastaneye yatış oranları grup 2 ve 3'e göre anlamlı olarak yüksekti; bunlar dışında gruplar arasında fark gözlenmedi (p=0,01, p=0,006 ve p=0,04, sırasıyla).

Tartışma: Düşük PI'li term SGA bebeklerde kısa dönem komplikasyonlar daha fazla görülmesine rağmen, tüm term SGA bebekler yüksek riskli yenidoğanlar olarak kabul edilmeli ve kısa dönem komplikasyonları önlemek için özellikli gözlem ve bakım yapılmalıdır.

Anahtar Kelimeler: Kısa dönem komplikasyon; morbidite; Ponderal indeks; SGA; term bebek.

INTRODUCTION

It has been recognized for many decades that the values of newborn weight and length at birth reflect the quality and quantity of growth of the fetus in utero (1). Fetal growth restriction (FGR), described as "all conditions leading to a marked reduction in size during intrauterine life," is linked to reduced birth weight (BW) (2). The term small for gestational age (SGA) is used to describe infants with a BW below the 10th percentile for that gestational age (GA) (3). The estimated rate of SGA is approximately 10% of term infants in developed countries and 20% of term infants in developing countries (4). Although FGR and SGA are mostly used as synonyms, they refer to different concepts. FGR is characterized by a lower fetal growth pattern than the expected growth potential of an infant due to a perinatal insult. However, at birth, these infants may have an appropriate BW for GA. Thus, FGR infants are those with clinical evidence of malnutrition (5). Hence, low BW itself does not include information about the neonate's body proportionality and is not a sufficient parameter to define growth restriction. During pregnancy, depending on the timing of the insult, a growth-restricted infant may have symmetric or asymmetric growth restriction. If both the weight and length of the neonate are affected, it is defined as a 'proportionately' or 'symmetrically' growth-restricted neonate. Proportionate growth restriction mostly results from genetic, infectious, or teratogenic insults early in utero. Conversely, infants with low BW and normal birth length (BL) are defined as 'disproportionately' or 'asymmetrically' growth-restricted neonates, occurring later in pregnancy as a result of hypoxemia and malnutrition due to placental insufficiency (6, 7). It should be noted that a neonate with a BW below the 10th percentile may be an SGA infant without FGR, while a neonate with a BW above the 10th percentile may have FGR (8). However, both groups of neonates are reported to have higher morbidity and mortality rates than normal BW infants. Moreover, during childhood, they may face a greater risk of metabolic syndromes, as well as neurologic and developmental delays (9).

The ponderal index (PI) is an indicator used to assess the growth pattern of SGA infants to determine the degree of fetal malnutrition. It allows differentiation between symmetric and asymmetric growth restriction. In addition, it evaluates the severity of asymmetry in growth-restricted infants. It is determined by the ratio of BW to BL (6, 10). According to the curves used, neonates below either the 3rd or 10th percentile for GA are considered to have fetal malnutrition or severe fetal wasting. Infants with asymmetrical SGA have a lower PI, which is associated with higher rates of morbidities such as hypoglycemia, polycythemia, early hyperbilirubinemia, hypothermia, perinatal resuscitation, perinatal asphyxia, fetal distress, or extended hospital stays in the neonatal period (11, 12).

The aim of this retrospective study was to determine the association between PI values and short-term complications of SGA term infants and to evaluate whether low PI is associated with higher morbidity.

MATERIAL AND METHODS

This is a retrospective study of singleton live births from January 2007 through May 2017, using the medical records of the pediatrics department of the hospital. These records contain information on maternal and neonatal demographics. The present study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the university hospital (approval date: 20.11.2017, number: 2017.178.IRB2.063).

Table 1. Baseline characteristic of the study groups

Parameters	Group 1 (PI<10 P) (n=45)	Group 2 (PI 10–90 P) (n=405)	Group 3 (PI>90 P) (n=39)	p
Gestational weeks, mean±SD	38.7±1.1	38.9±1.13	38.6±1	0.06
Weight (g), mean±SD	2410±338	2630±218	2635±153	<0.001
Length (cm), mean±SD	47.9±2.5	46.9±1.5	44.6±1.2	<0.001
Head circumference (cm), mean±SD	32.8±1.6	33.3±1.1	33.1±1	0.02
Ponderal index, mean±SD	2.2±0.1	2.5±0.14	2.96±0.17	<0.001
Male gender, n (%)	15 (33.3)	142 (35.1)	10 (25.6)	0.5
C-section, n (%)	32 (71.1)	288 (71.1)	27 (69.2)	0.97
Perinatal resuscitation in the delivery room, n (%)	1 (2.2)	11 (2.7)	2 (5.1)	0.7
5th minute Apgar score, median (25–75 p)	10 (10–10)	10 (10–10)	10 (10–10)	0.2

SD: Standard deviation; PI: Ponderal Index.

Medical records of all newborns born in that period (n=11,938) were reviewed. Babies born to mothers with pathologies affecting the intrauterine growth of the fetus, such as infants of diabetic mothers and infants born to preeclamptic mothers, were not included. Neonates with clinical evidence of chromosomal abnormality, gross congenital abnormalities or lethal malformations, stillbirths, multiple births, and those with uncertain GA were excluded.

In all cases, GA was calculated based on the mother's last menstrual period and the first-trimester ultrasound. BW, BL, and head circumference (HC) were measured on arrival in the nursery by neonatal nurses. BW was measured using an electronic scale (Seca 354) calibrated to 10 g. BL was determined by measuring crown-heel length with a portable infantometer (Seca) with a range of 1 to 75 cm, calibrated to 1 mm. HC was measured with a tape encircling the head from the frontal area above the glabella to the most prominent portion of the occiput posteriorly. Term infants (37–42 weeks) whose BW was below the 10th percentile according to the growth curves for the Turkish population were considered SGA infants and included in the study (13). Of the 495 neonates, 6 were excluded due to congenital heart anomaly (n=4), diaphragmatic hernia (n=1), and omphalocele (n=1). Finally, a total of 489 infants were included in the study.

PI was calculated using the following formula:

$$PI = \frac{\text{birthweight in grams x 100}}{\text{length}^3 \text{ in centimeters}}$$

The PI values of SGA infants were plotted on the percentile curves of Miller and Hassanein (14). According to the PI values, the neonates were classified as low PI (PI<10th percentile), appropriate PI (PI 10th–90th percentile), and high PI (PI>90th percentile), corresponding to groups 1, 2, and 3, respectively.

Other data collected included information regarding gender, mode of delivery, need for perinatal resuscitation, 5th-minute APGAR score, body temperature (˚C) on admission, jaundice requiring treatment, respiratory distress, hospitalization and rehospitalization rates, duration of hospitalization, degree of weight loss (%), need for noninvasive ventilation, lowest blood glucose level, complete blood count, and thyroid function tests. Hypothermia was defined as an axillary body temperature below 36˚C (15). Hypoglycemia was defined as a blood glucose concentration below 45 mg/dL (16), polycythemia as a venous hemoglobin level exceeding 22 g/dL (17), neutropenia as an absolute neutrophil count less than 1000 cells/mm^3 (18), and thrombocytopenia as a platelet count less than 150,000/mm^3 (19).

Statistical Analysis

We used SPSS software for Windows, version 20.0 (SPSS Inc., Chicago, IL, USA) for statistical analyses. Variables were investigated using visual (histograms, probability plots) and analytical methods (Shapiro-Wilk test) to determine if they were normally distributed. Descriptive analyses were presented as means±SD for normally distributed variables, as medians (range, 25–75 p) for nonparametric variables, and as percentages for categorical variables. Normally distributed variables were compared by one-way ANOVA, nonparametric variables by the Friedman test, and categorical variables by the chi-square test. Spearman's correlation analysis was performed to detect any correlation between GA and PI of the infants. p<0.05 was considered to indicate a significant difference.

RESULTS

Of the 11,938 neonates, there were 555 (4.6%) SGA infants, of whom 495 were term babies. After excluding 6 infants due to congenital anomalies, group 1 consisted of 45 neonates (9.2%) whose PI was below the 10th percentile, while 405 neonates (82.8%) with a PI between the 10th and 90th percentile and 39 neonates (8%) with a PI above the 90th percentile constituted groups 2 and 3, respectively. The demographic characteristics of group 1, group 2, and group 3 SGA infants are shown in Table 1. The incidence of hypoglycemia, jaundice requiring treatment, and hospitalization rate were significantly higher

Table 2. Adverse outcomes and morbidity pattern of the study groups

Parameters	Group 1 (PI<10 P) (n=45)	Group 2 (PI 10–90 P) (n=405)	Group 3 (PI>90 P) (n=39)	p
Jaundice needed to be treated, n (%)	8 (17.8)	24 (5.9)	1 (2.6)	0.006
Respiratory distress, n (%)	3 (6.7)	14 (3.5)	1 (2.6)	0.5
Hospitalization, n (%)	7 (15.6)	24 (5.9)	2 (5.1)	0.04
Rehospitalization, n (%)	5 (11.1)	41 (10.1)	7 (17.9)	0.3
Perinatal resuscitation in the delivery room, n (%)	1 (2.2)	11 (2.7)	2 (5.1)	0.7
Percentage of weight loss (%)	7.1±2.6	6.8±2.2	6.9±2.7	0.6
Noninvasive ventilation, n (%)	2 (4.4)	6 (1.5)	0	0.2
Hypoglycemia, n (%)	18 (45)	90 (24.2)	7 (18.9)	0.01
TSH level (mIU/L), median (25–75 p)	7.2 (5.3–15.2)	6.6 (3.6–10.6)	7.6 (3.8–10.6)	0.3

PI: Ponderal Index.

Table 3. The results of the laboratory findings of the term SGA infants in all groups

Parameters	Group 1 (n=11)	Group 2 (n=45)	Group 3 (n=5)	p
Hemoglobin (g/dL)	17.8±2.1	17.9±2.8	15.1±2.2	0.09
Leucocytes (/mm^3), median (25–75 p)	15.360, 7620–17.760	13.600, 11.490–20.965	11.470, 8780–29.910	0.8
Neutrophil count (/mm^3), median (25–75 p)	6385, 3163–13.729	8500, 5704–13.665	5510, 4655–12.575	0.6
Platelet count (/mm^3), median (25–75 p)	167.000, 96.000–288.000	242.000, 172.500–283.000	216.000, 151.500–239.500	0.38
Thrombocytopenia, n (%)	5 (45.5)	10 (22.2)	1 (20)	0.28

SGA: Small for gestational age.

in infants with low PI (group 1) (p=0.01, p=0.006, and p=0.04, respectively). Adverse outcomes and morbidity patterns of the study groups are demonstrated in Table 2. There was a significant inverse correlation between the blood glucose and bilirubin levels of the infants (r=-0.28, p<0.001), indicating that as blood glucose levels increased, bilirubin levels decreased. Complete blood count was obtained only from 61 infants (Table 3). Thrombocytopenia was observed in 45.5% of infants in group 1 and 22.2% and 20% of infants in groups 2 and 3, respectively; however, the difference was not statistically significant. Only five infants in group 2 had polycythemia. Five infants had a body temperature below 36˚C, all of whom were also in group 2. However, both morbidities, which were observed only in group 2, were not statistically significant.

None of the infants experienced severe morbidity or died. Nine infants (1.84%) had meconium-stained amniotic fluid, but only one was hospitalized due to meconium aspiration, and another due to perinatal asphyxia; both had a PI within the 10th–90th percentile.

There was no correlation between GA and PI values (r=0.018, p=0.69).

DISCUSSION

Suboptimal fetal growth resulting in an SGA infant or FGR is an important issue linked to increased morbidity and mortality rates, decreased lifespan, and higher costs of care. Approximately five decades ago, it was reported that SGA infants born at term had a 6-fold increased risk for neonatal mortality and a 3-fold increased risk for neonatal morbidities compared with term appropriate for gestational age (AGA) infants (20). Previous studies have shown that asymmetric SGA infants (infants with PI<10th percentile) have higher neonatal morbidity than symmetric SGA infants (infants with PI>10th percentile) in terms of acute neonatal outcomes, including metabolic and hematological disturbances as well as disrupted thermoregulation (1, 4). In this study, we found that term SGA infants with low PI had a higher risk of hypoglycemia, jaundice requiring treatment, and hospitalization than SGA infants with appropriate or high PI. None of the infants died or experienced life-threatening complications due to growth restriction.

SGA infants face various medical problems after birth. Severely affected infants, deprived of oxygen and nutrients, may experience difficult cardiopulmonary transition and develop perinatal asphyxia, meconium aspiration, or persistent pulmonary

hypertension. Due to respiratory distress, gastrointestinal issues, metabolic and hematologic disturbances, the hospitalization rates are higher in SGA infants than in AGA infants (1, 12, 21). Among our subjects, only one developed perinatal asphyxia, and none developed persistent pulmonary hypertension. Although nine infants had meconium-stained amniotic fluid, only one with an appropriate PI developed meconium aspiration syndrome. However, in our study, the hospitalization rates of SGA infants with low PI (15.6%) were higher than those of infants with appropriate and high PI (5.9% and 5.1%, respectively) (p=0.04).

Hypothermia is another common complication in these infants due to inadequate temperature control measures. A relatively large body surface area, low body and subcutaneous fat, impaired thermoregulation, and catecholamine consumption, as well as the simultaneous occurrence of hypoglycemia and hypoxia, are the main causes of hypothermia (12, 21, 22). In this study, hypothermia was observed in only five infants, all of whom had appropriate PI (group 2), which was not statistically significant.

In the first days of life, hypoglycemia becomes a major concern for SGA infants due to delayed postnatal metabolic adaptation. This condition can arise from low glycogen stores, decreased gluconeogenesis, increased insulin sensitivity, low fat levels, and a decreased ability to oxidize free fatty acids and triglycerides. Additionally, perinatal asphyxia, polycythemia, and hypothermia can exacerbate hypoglycemia (12, 21, 23). Many studies recommend screening SGA infants for hypoglycemia within the first 24 hours of life. There is no single set blood glucose concentration below which hypoglycemia is definitively linked to neurological deficits. According to the AAP, the target plasma glucose concentration should be 45 mg/dL or higher for all infants (16). Doctor et al. (9) compared 372 SGA infants with an equal number of AGA infants, demonstrating that SGA infants had significantly higher rates of hypoglycemia (5%) compared to AGA infants (1%). Deorari et al. (24) noted that of 144 SGA infants, 24 (17%) developed hypoglycemia, with a higher risk (25.5%) among those whose BW was <3rd percentile compared to those between the 3rd–10th percentile. Nili et al. (11) conducted a study with 361 term SGA infants, reporting that hypoglycemia was significantly higher in term SGA infants with low PI compared to infants with appropriate and high PI. In the present study, the incidence of hypoglycemia was the highest in infants with low PI, with 45% experiencing hypoglycemia in this group, while hypoglycemia was the lowest in infants with PI over the 90th percentile (18.9%), which was statistically significant (p=0.01). This result is logical, as PI increases with BW, thereby providing more glycogen stores to the infants.

Jaundice (indirect hyperbilirubinemia) is known to be associated with growth restriction in term infants, possibly due to decreased liver size and immaturity of liver function (25, 26). In this study, we demonstrated that the rate of jaundice requiring phototherapy was 17.8% in low PI SGA infants, which was higher than in the other two groups (5.9% and 2.6% in infants with appropriate and high PI, respectively) and was statistically significant (p=0.006).

We included only term infants in our study and, therefore, found no correlation between GA and PI, though PI values increase with GA up to the 37th week of gestation and then remain constant (14).

Limitations

The present study has some limitations. First, measurements were performed by several newborn nurses, and as the study is retrospective, this may explain discrepancies among the groups. Secondly, the maternal socio-cultural and socio-economic levels were higher than average, which may not reflect the general population. Additionally, data on maternal characteristics and records of maternal weight gain during pregnancy were unavailable, which could help determine an association between poor maternal weight gain and low PI.

In conclusion, in the present study, we demonstrated that SGA infants with PI levels below the 10th percentile appear to have higher short-term complications, including hypoglycemia, jaundice requiring treatment, and hospitalization, than other SGA infants. However, independent of PI, all SGA infants should be considered high-risk neonates and monitored closely for early identification of any short-term complications during the neonatal period. This study does not provide data on the long-term outcomes of these infants. It is also recommended to follow all SGA infants, including low PI infants, in terms of neurological, cognitive, and metabolic outcomes in the long term and to evaluate these infants according to their long-term outcomes as well.

Ethics Committee Approval: The Koç University Clinical Research Ethics Committee granted approval for this study (date: 20.11.2017, number: 2017.178.IRB2.063).

Authorship Contributions: Concept – SE, TG; Design – SE, YC, TG; Supervision – TG; Fundings – TG, YC; Materials – SE, TG; Data collection and/or processing – SE, TG; Analysis and/or interpretation – TG, YC; Literature review – YC; Writing – YC, TG; Critical review – TG.

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