

# The Correlation of Cord Arterial Blood Gas Analysis Results and Apgar Scores in Term Infants Without Fetal Distress

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## What is already known on this topic?

- The Apgar score is used to quickly assess the clinical condition of the newborn at 1- and 5-minute after birth.
- Especially a 5-minute Apgar score below 7 indicates an increased risk of neonatal asphyxia.
- Cord arterial blood gas analysis (ABGA) is necessary for evaluating neonatal acidemia but is generally not recommended for every delivery. However, routine cord ABGA is recommended for all high-risk deliveries.

## What this study adds on this topic?

- Some parameters in cord blood gas may be outside the normal range in term newborns with normal Apgar scores.
- Evaluation of routine cord ABGA at every term newborn delivery, even if there are no signs of fetal distress and normal Apgar scores, may be useful for detecting cases with mild metabolic acidosis and for elevated lactate levels to closely follow up these cases.

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## ABSTRACT

**Objective:** This study aimed to evaluate the necessity of cord arterial blood gas analysis in cases without fetal distress and normal Apgar score.

**Materials and Methods:** The cord arterial blood gas analysis and the 1- and 5-minute Apgar scores data of 1438 cases were evaluated. Newborns with fetal distress, neonates requiring cardiopulmonary resuscitation in the delivery room, congenital anomalies, severe and moderate acidemia (pH  $\leq 7.1$  at cord arterial blood gas analysis), and pre- and post-term newborns are excluded. Following cord arterial blood gas analysis, threshold values were accepted as abnormal pH  $< 7.2$ , base excess  $\geq -6$  mmol/L, lactate  $\geq 5$  mmol/L, bicarbonate  $< 18$  mmol/L, and partial pressure of carbon dioxide  $\geq 50$  mmHg. We evaluated the correlation between cord arterial blood gas analysis and 1- and 5-minute Apgar scores.

**Results:** There was a significant correlation between both 1- and 5-minute Apgar scores and cord arterial blood gas analysis values such as pH, lactate, and partial pressure of carbon dioxide ( $P < .001$ ). In addition, a significant correlation was found between the 5-minute Apgar score of  $< 7$  and some cord arterial blood gas analysis abnormal threshold values (pH, bicarbonate, base excess) ( $P < .001$ ). We found that some patients with mild acidemia had 1- and 5-minute Apgar scores of  $\geq 7$  in 1.9% and 2% of cases, respectively.

**Conclusion:** The 5-minute Apgar score of 7 or higher may not be sufficient to verify the well-being of a newborn. Relying only on the Apgar scores may create the risk of missing some newborns with mild metabolic acidosis. The necessity of routine cord arterial blood gas analysis should be considered in prospective studies even if there are no signs of fetal distress and Apgar score  $\geq 7$ .

**Keywords:** Apgar score, cord arterial blood gas, newborn, term infant

## INTRODUCTION

The Apgar score is a simple, reproducible scoring system developed by Virginia Apgar in 1952 to evaluate the postnatal condition of the newborn.<sup>1</sup> This scoring is used to quickly assess the clinical condition of the newborn at 1- and 5-minute after birth. The Apgar score is obtained by evaluating 5 parameters (skin color, heart rate, reflexes, muscle tone, and respiratory activity).<sup>1,2</sup> Especially, a 5-minute Apgar score below 7 indicates an increased risk of neonatal asphyxia.<sup>3</sup> This scoring system may be affected by prematurity, congenital anomalies, maternal drug use, and interobserver variability.<sup>4</sup> However, recent literature shows that the Apgar score is effective in predicting neonatal well-being as it has been

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accepted for many years.<sup>5</sup> The Apgar score may decrease in association with gestational age but cannot predict morbidity or mortality for each newborn. It is used worldwide to assess babies' condition immediately after birth and evaluate resuscitation effectiveness. The Apgar score has never been designed to predict the outcome beyond the postpartum period.<sup>6</sup>

Cord artery blood gas analysis (ABGA) is used to help evaluate newborns' health status. Artery blood gas analysis allows assessing a patient's circulation, respiration, metabolic and electrolyte status, or hypoxia.<sup>7</sup> Cord ABGA, especially pH, base excess (BE), and lactate, is evaluated after birth. The reference value for BE is from  $-2$  to  $+2$  mmol/L. When this value is negative, there is a lack of base, and the patient is in a state of metabolic acidosis. Lactate is produced by cellular metabolism in hypoxic conditions, with less energy production, leading to overproduction or poor elimination of lactates. Different studies have reported average umbilical arterial lactate values ranging from 2.55 to 4.63 mmol/L.<sup>8</sup> pH is the result of the balance between lactate, which tends to lower the pH, and BE, which stabilizes it.<sup>9</sup> Cord ABGA is necessary for evaluating neonatal acidemia but is not generally recommended for every delivery. However, routine cord ABGA is recommended for all high-risk deliveries.<sup>10</sup> In the meta-analysis by Malin et al.<sup>11</sup> evaluating cord ABGA pH value and perinatal and long-term outcomes, it was reported that  $\text{pH} < 7.2$  is associated with increased mortality and morbidity.

Cord ABGA values and the Apgar score are the 2 parameters that provide the fastest information about a baby's well-being after birth. We hypothesized that Apgar scores may not be sufficient for a complete and accurate evaluation of newborns and may be insufficient to detect cases with mild acidemia and lactate elevation at birth. This study aimed to show the incidence of abnormal cord ABGA in otherwise healthy term newborns. We also evaluated the correlation between Apgar scores and cord ABGA in all term newborns without any known risk factors causing fetal distress.

## MATERIALS AND METHODS

### Patients and Data

This study was carried out in a university hospital where high-risk pregnancies are followed up in the Perinatology Department. The cord ABGA has been routinely performed in order to evaluate the acidic status of newborns in all deliveries since 2015. We showed that, otherwise healthy term newborns may be born with abnormal, acidic cord ABGA and may need a special follow-up. This retrospective study analyzed the data of 1781 babies born between January 2018 and December 2019 at Cerrahpasa Faculty of Medicine. Unfollowed pregnancies, neonates requiring cardiopulmonary resuscitation in the delivery room, congenital anomalies, severe and moderate acidemia ( $\text{pH} \leq 7.1$  at cord ABGA), and pre- and post-term newborns were excluded. Finally, the cord ABGA and the 1- and 5-minute Apgar score data of 1438 cases were evaluated (Figure 1).

Ethics approval was obtained from Ethics Committee (reference no: 162202).

Cord blood gases were taken into heparinized injectors in the form of at least 1.5 mL of both arterial blood gas

without cord clamping. Samples were measured by ABL Flex (Radiometer) within 20 minutes.

### Definitions

Based on the International Federation of Gynecology and Obstetrics classification system, newborns with a preliminary diagnosis of fetal distress were excluded from the study.<sup>12</sup>

Apgar scores were calculated by pediatric senior residents and midwives, all certified in the neonatal resuscitation program. In the literature, a 5-minute Apgar score between 7 and 10 had been determined as a safe range in terms of neonatal encephalopathy and long-term neurological outcomes.<sup>13,14</sup> Therefore, in this study, an Apgar score between 7 and 10 was considered normal and  $<7$  as low.

Cord ABGA threshold values indicating perinatal asphyxia had been reported as  $\text{pH} < 7.0$  and  $\text{BE} \geq -12$  in some meta-analyses.<sup>15</sup> In this study, threshold values set for severe, moderate, and mild acidemia in cord ABGA were accepted as  $\text{pH} \leq 7.0$  and  $\text{pH}$  between 7.0 and 7.1, and  $\text{pH}$  between 7.1 and 7.2, respectively.<sup>3</sup> Cases with a pH value above 7.1 in cord ABGA were included in the study. Abnormal cord ABGA threshold values were accepted as  $\text{pH} < 7.2$ ,  $\text{BE} > -6$  mmol/L, lactate  $\geq 5$  mmol/L, bicarbonate ( $\text{HCO}_3$ )  $< 18$  mmol/L, and partial pressure of carbon dioxide ( $\text{pCO}_2$ )  $\geq 50$  mmHg according to the previous studies.<sup>14–15</sup>

In this study, we first evaluated the correlation between 1- and 5-minute Apgar scores and cord ABGA. Subsequently, we studied the correlation between low 1- and 5-minute Apgar scores of  $<7$  and abnormal threshold values of cord ABGA parameters.

### Statistical Analysis

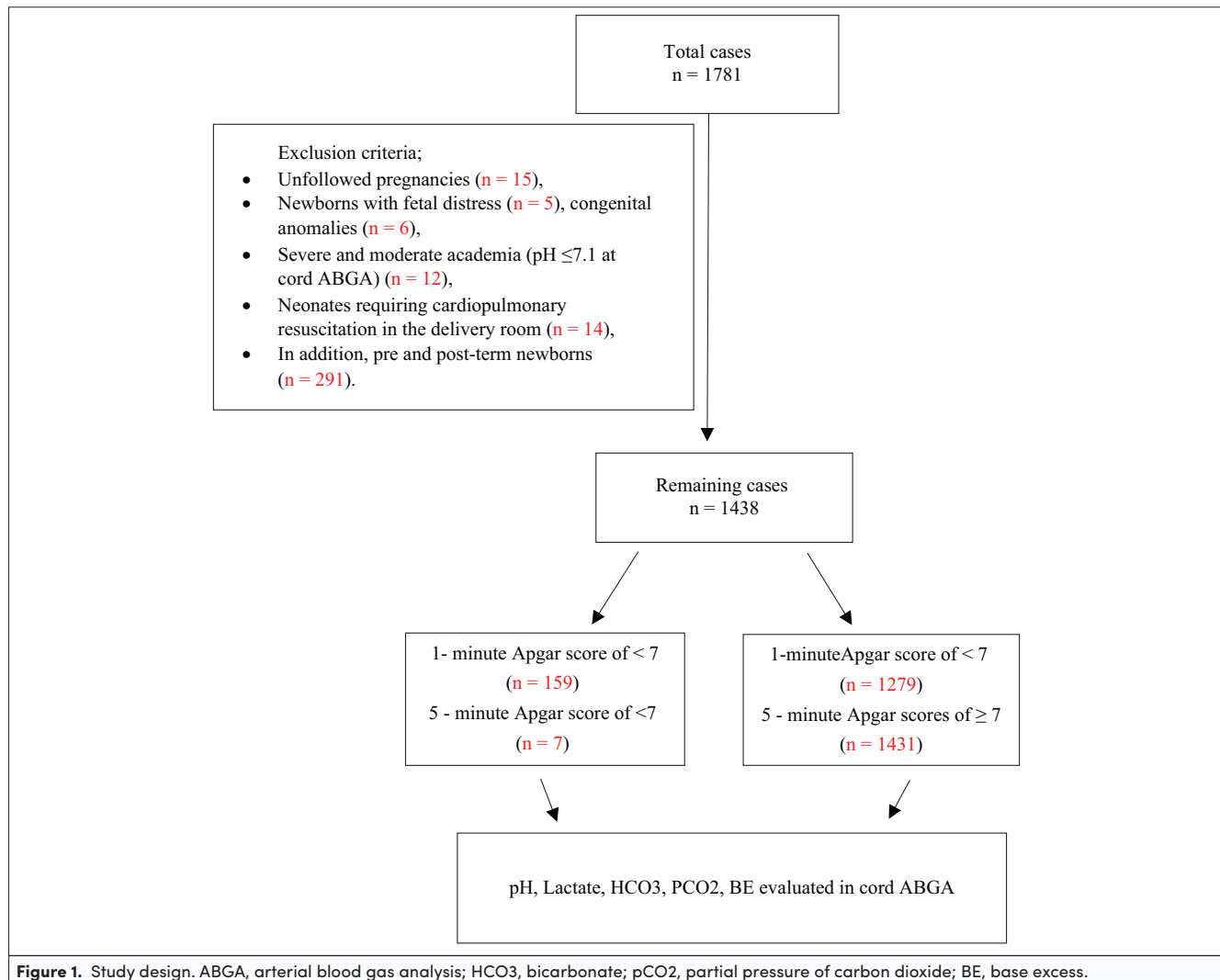
Statistical Package for the Statistical Package for Social Sciences version 21.0 software (IBM Corp.; Armonk, NY, USA) was used for statistical analysis. Continuous variables (Apgar score, pH, lactate,  $\text{HCO}_3$ ,  $\text{pCO}_2$ , BE) were presented as median (min-max) and as mean  $\pm$  standard deviation and/or median (min-max). Categorical variables were presented as frequency and percentage. Spearman's correlation was used to determine the correlation between continuous variables, and Phi correlation was used to determine the correlation between categorical variables. The significance level was accepted as  $P < .05$ .

## RESULTS

A total of 1438 term newborns were included in the study. The study group had a median (min-max) gestational age of 38<sup>6/7</sup> (37<sup>0/7</sup>–41<sup>6/7</sup>) weeks and birth weight of 3270 (2020–5295) g. Totally, 698 (48.5%) of the cases were female and 740 (51.5%) were male, and 366 (25.4%) of the cases were born by vaginal delivery and 1072 (74.5%) by cesarean.

The mean  $\pm$  standard deviation data of all cases were as follows: 1-minute Apgar score was  $7.65 \pm 1.05$ , 5-minute Apgar score was  $8.88 \pm 0.73$ , pH was  $7.34 \pm 0.056$ , lactate (mmol/L) was  $2.37 \pm 1.68$ ,  $\text{HCO}_3$  (mmHg) was  $21.82 \pm 2.13$ ,  $\text{pCO}_2$  (mmHg) was  $44.27 \pm 7.97$ , and BE (mEq/L) was  $-2.33 \pm 2.59$ .

When the association between Apgar scores (1- and 5-minute) and cord ABGA parameters (pH, lactate, BE,  $\text{HCO}_3$ ,



pCO<sub>2</sub>) was evaluated, a significant correlation was found between pH, lactate, pCO<sub>2</sub>, and Apgar scores (1- and 5-minute) ( $P < .001$ ). This correlation ratio was very weak ( $r = 0.01-0.19$ ), with 1-minute Apgar score and cord ABGA correlation ratio being highest with lactate ( $r = 0.119$ ) and lowest with pH ( $r = 0.092$ ), and 5-minute Apgar score and cord ABGA correlation ratio was highest with pCO<sub>2</sub> ( $r = 0.116$ ) and lowest with pH ( $r = 0.095$ ). There was no significant correlation between HCO<sub>3</sub>, BE, and Apgar scores (Table 1).

No association was found between any abnormal threshold values of cord ABGA (pH, lactate, BE, HCO<sub>3</sub>, pCO<sub>2</sub>) and a 1-minute Apgar score of <7 (Table 2).

A statistically significant correlation was detected between a 5-minute Apgar score of <7 and pH, HCO<sub>3</sub>, and BE abnormal threshold values ( $P < .001$ ). This correlation ratio was very weak ( $r = 0.01-0.19$ ), the correlation ratio was highest with pH ( $r = 0.130$ ) and slightest with HCO<sub>3</sub> ( $r = 0.072$ ). There was no significant correlation between lactate and pCO<sub>2</sub> abnormal threshold values and a 5-minute Apgar score (Table 3). In the evaluation of cord ABGA in patients with 5-minute Apgar score of ≥7, in 92 cases, the lactate value was ≥5 mmol/L; in 28 cases,

**Table 1.** The Relationship Between Cord Artery Blood Gas Analysis and 1- and 5-Minute Apgar Scores

Measurements	Participants, (n) mean ± standard deviation	Apgar Score (1-Minute)	Apgar Score (5-Minute)
		1438 7.6 ± 1.04	1438 8.8 ± 0.71
pH	<i>r</i>	0.092	0.095
	<i>P</i>	<b>&lt;.001</b>	<b>&lt;.001</b>
Lactate (mmol/L)	<i>r</i>	0.119	0.114
	<i>P</i>	<b>&lt;.001</b>	<b>.001</b>
HCO <sub>3</sub> (mmHg)	<i>r</i>	0.028	0.024
	<i>P</i>	.297	.366
pCO <sub>2</sub> (mmHg)	<i>r</i>	0.113	0.116
	<i>P</i>	<b>&lt;.001</b>	<b>&lt;.001</b>
BE (mEq/L)	<i>r</i>	0.004	0.017
	<i>P</i>	.887	.524

Spearman correlation:  $r = 0.01-0.19$ , very weak relationship;  $r = 0.20-0.29$ , weak relationship;  $r = 0.30-0.39$ , medium relationship;  $r = 0.40-0.69$ , strong relationship;  $r = \geq 0.70$ , very strong relationship. Bold values indicate statistically significant ( $P < .05$ ).

HCO<sub>3</sub>, bicarbonate; pCO<sub>2</sub>, partial pressure of carbon dioxide; BE, base excess.

**Table 2.** The Relationship Between the Threshold Values of Cord Artery Blood Gas Analysis and the 1-Minute Apgar Score

		Apgar Score <7 n = 159	Apgar Score ≥7 n = 1279	φ	P
Measurement	Threshold				
pH	<7.2	6 (3.8)	24 (1.9)	0.042	.114
	≥7.2	153 (96.2)	1255 (98.1)		
Lactate (mmol/L)	<5	150 (94.3)	1195 (93.4)	0.012	.661
	≥5	9 (5.7)	84 (6.6)		
HCO <sub>3</sub> (mmHg)	<18	8 (5.0)	69 (5.4)	-0.005	.848
	≥18	151 (95.0)	1210 (94.6)		
pCO <sub>2</sub> (mmHg)	<50	118 (74.2)	1001 (78.3)	-0.031	.246
	≥50	41 (25.8)	278 (21.7)		
BE (mEq/L)	≥-6	17 (10.7)	102 (8.0)	0.031	.241
	<-6	142 (89.3)	1177 (92.0)		

Data are given as number (%); Phi correlation: φ = 0.01-0.19, very weak relationship; φ = 0.20-0.29, weak relationship; φ = 0.30-0.39, medium relationship; φ = 0.40-0.69, strong relationship; φ = ≥0.70, very strong relationship. Bold values indicate statistically significant (P < .05). HCO<sub>3</sub>, bicarbonate; pCO<sub>2</sub>, partial pressure of carbon dioxide; BE, base excess.

pH value was <7.2; in 75 cases, HCO<sub>3</sub> value was <18 mmol/L; and in 116 cases, BE value was <-6 mEq/L (Table 3). Metabolic acidosis and lacticemia values were not detected in patients whose first cord ABGA showed mild acidemia and lacticemia before discharge, and there were no pathological findings related to their physical examination and nutrition.

## DISCUSSION

This study evaluated the association between Apgar scores and cord ABGA in term newborns who were not known to have fetal distress at the prenatal period. We found a correlation between

**Table 3.** The Relationship Between the Threshold Values of Cord Artery Blood Gas Analysis and the 5-Minute Apgar Score

		Apgar Score <7 n = 7	Apgar Score ≥7 n = 1431	φ	P
Measurement	Threshold				
pH	<7.2	2 (28.6)	28 (2.0)	0.130	<b>&lt;.001</b>
	≥7.2	5 (71.4)	1403 (98.0)		
Lactate (mmol/L)	<5	6 (85.7)	1339 (93.6)	-0.022	.399
	≥5	1 (14.3)	92 (6.4)		
HCO <sub>3</sub> (mmHg)	<18	2 (28.6)	75 (5.2)	0.072	<b>.006</b>
	≥18	5 (71.4)	1356 (94.8)		
pCO <sub>2</sub> (mmHg)	<50	4 (57.1)	1115 (77.9)	-0.035	.187
	≥50	3 (42.9)	316 (22.1)		
BE (mEq/L)	≥-6	3 (42.9)	116 (8.1)	0.088	<b>.001</b>
	<-6	4 (57.1)	1315 (91.9)		

Data are given as number (%); Phi correlation: φ = 0.01-0.19, very weak relationship; φ = 0.20-0.29, weak relationship; φ = 0.30-0.39, medium relationship; φ = 0.40-0.69, strong relationship; φ = ≥0.70, very strong relationship. HCO<sub>3</sub>, bicarbonate; pCO<sub>2</sub>, partial pressure of carbon dioxide; BE, base excess.

cord ABGA parameters (pH, lactate, and PCO<sub>2</sub>) and Apgar score both at 1- and 5-minute. An association was also found between a low 5-minute Apgar score of <7 and pH, HCO<sub>3</sub>, and BE abnormal threshold values. It has been shown that pH is the most important parameter to show the acidemia status in cord blood gas and it is a result of the balance between lactate and BE from other parameters.<sup>9,16</sup> Similarly, our results showed that pH, one of the cord ABGA parameters, is important to demonstrate mild acidemia. While the 1-minute Apgar score does not provide much information about the newborn's long and short-term outcomes, the 5-minute Apgar score is more valuable. It has been reported that any 1-minute Apgar score between 0 and 3 does not predict the outcome of the newborn.<sup>17</sup> However, a low 5-minute Apgar score indicates an increased relative risk of cerebral palsy, which is reported to be 20-100 times higher than that of infants with a 5-minute Apgar score of 7-10.<sup>18,19</sup> The relevant literature also reports a correlation between a low 5-minute Apgar score and neonatal hypoxia and mortality.<sup>20,21</sup> Currently, pH and BE values in cord ABGA are considered to determine newborns who have experienced antenatal hypoxia requiring hypothermia to prevent the poor outcome.<sup>22</sup> Similarly, in our study, it was observed that abnormal cord ABGA values of pH, HCO<sub>3</sub>, and BE were associated with a low 5-minute Apgar score (Table 3).

One of the crucial findings of this study is the presence of cases with normal Apgar scores but abnormal cord ABGA parameters. A recent large-scale study by Sabol et al<sup>3</sup> showed abnormal results in cord ABGA of newborns with normal Apgar scores. In this study, 6.6% of cases had an increased lactate level (>5 mmol/L), and 5.4% had decreased HCO<sub>3</sub> even with a normal 1-minute Apgar score. About 2% of the newborns were mild acidotic (pH between 7.1 and 7.2), and 6.4% had increased lactate levels with a normal 5-minute Apgar score. In cord ABGA, pH < 7.0 and base deficit ≥ -12 values are generally accepted cut-off values that increase the risk of pathological acidosis, seizures, neonatal encephalopathy, and cerebral palsy.<sup>3,19</sup> If the pH value is higher than 7.2 in cord ABGA, the risk of neonatal encephalopathy is negligible. However, the risk of encephalopathy continues in newborns with a pH below 7.2.<sup>3,23,24</sup> In a prospective study by Mousa et al.<sup>25</sup> when the short-term results of cases with pH above and below 7.2 in cord ABGA were examined, it was found that resuscitation, convulsions, hypoxic encephalopathy, hospitalization, and hospital stay were longer in cases with cord ABGA pH below 7.2. High lactate values are closely associated with metabolic acidosis, mortality, and morbidity and can be used as a predictive marker of end tissue oxygenation.<sup>26-28</sup> It has been reported in previous studies that a high lactate value can be regarded as a poor prognostic factor, but a definite cut-off value has not been given.<sup>29,30</sup> For these reasons, it would be reasonable to detect and closely follow up newborns with the stable postnatal clinic and normal Apgar scores but abnormal cord ABGA. We planned another study to evaluate the neurological development of patients with normal Apgar scores but high lactate levels in their cord ABGA.

Our study found the mean pH value in term newborns without any fetal distress to be 7.34 ± 0.056. Previous studies found the pH of cord ABGA in uncomplicated deliveries between 7.24 and 7.27.<sup>31,32</sup> In addition, in a comprehensive study conducted by



Helwig et al.<sup>15</sup> pH of  $7.26 \pm 0.07$  was found in cord ABGA of 5-minute Apgar score of  $\geq 7$  term babies. In our study, similar to previous studies, most patients (98%) with a normal 5-minute Apgar score had a pH value  $\geq 7.2$  at cord ABGA. In our study, the mean BE value in the cord ABGA of term newborns was  $-2.33 \pm 2.59$  mEq/L. Base excess value in cord ABGA in uncomplicated term deliveries had been reported to be between  $-5.6$  and  $-2.7$  mEq/L.<sup>15,33</sup> Similar to previous studies, in our study, the BE value in cord ABGA of term newborns with the 5-minute Apgar score value of  $\geq 7$  was found to be  $< -6$  mEq/L in most cases (91.9%). In the study of Helwig et al.<sup>15</sup> in newborns with a 5-minute Apgar score of  $\geq 7$ , the pCO<sub>2</sub> value was  $53 \pm 10$  mmHg. This value was higher than the mean of our study ( $44.27 \pm 7.97$  mmHg). These different results might be attributed to the inclusion of preterm newborns in the study conducted by Helwig et al.<sup>15</sup> In our study, the mean HCO<sub>3</sub> value in cord ABGA of term newborns was  $21.82 \pm 2.13$  mmHg. The average level of HCO<sub>3</sub> in blood gas has been reported to be approximately 20 in term newborns.<sup>31</sup> In our study, similar to previous studies, we found the HCO<sub>3</sub> value in the cord ABGA of term newborns with the 5-minute Apgar score value of  $\geq 7$  to be  $\geq 18$  mmHg in most cases (94,8%).

The main limitation of our study is that it is a retrospective study, and the interobserver variability for evaluating the Apgar score can also be considered a limiting factor. Another limitation of our study is that the correlation coefficients were very weak. On the other hand, the strength is that it seems to be the only study in the literature evaluating the association between cord ABGA and the Apgar score in newborns without perinatal risk factors.

In conclusion, we showed that all newborns without fetal distress should be evaluated with cord ABGAs to avoid missing the mild perinatal acidosis and other abnormal parameters. A prospective study evaluating especially the neuromotor development and neurological outcomes of newborns with mild acidemia and lacticemia in their cord ABGA despite a normal Apgar score is needed. The routine cord ABGA on term infants, even without any signs of fetal distress and Apgar scores of  $\geq 7$ , would identify neonates with mild acidosis. This finding would help plan a close follow-up process for these neonates.

**Ethics Committee Approval:** The study was approved by Ethics committee of Istanbul University-Cerrahpasa (Approval No: 162202).

**Informed Consent:** Verbal informed consent was obtained from all individuals included in this study.

**Peer-review:** Externally peer-reviewed.

**Author Contributions:** Concept – A.Y., M.V.; Design – A.Y., M.V.; Supervision – M.V., Y.P.; Resources – A.Y., N.K., I.U., H.E.T., D.K.; Materials – A.Y., I.U., H.E.T.; Data Collection and/or Processing – A.Y., N.K., I.U., H.E.T., D.K.; Analysis and/or Interpretation – A.Y., H.C.A.; Literature Search – A.Y., M.V.; Writing Manuscript – A.Y., M.V.; Critical Review – A.Y., M.V., Y.P.

**Declaration of Interests:** The authors have no conflict of interest to declare.

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