The Turkish Journal of Pediatrics 1996; 38: 447-457

THE RELATIONSHIP BETWEEN APGAR SCORE AND UMBILICAL ARTERIAL BLOOD GAS VALUES IN NEWBORNS*

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SUMMARY: Energin M, Karakelleoğlu C, Orbak Z, Alp H, Selimoğlu MA, Ersoy M. (Department of Pediatrics, Atatürk University Faculty of Medicine, Erzurum, Turkey). The relationship between Apgar score and umbilical arterial blood gas values in newborns. Turk J Pediatr 1996; 38: 447-457.

The data for this report were derived from 61 newborns and their mothers. Of the newborns 45.9 percent had one-minute Apgar scores of less than seven, and 54.1 percent had Apgar scores of seven or greater. The five-minute Apgar score was less than 7 in 6.6 percent of cases.

While 23 percent of newborns had pH values of less than 7.20, 77 percent had pH of 7.20 or greater. Only 39.3 percent of the 28 newborns with one-minute Apgar score of less than 7 and 75 percent of the four newborns with five minute Apgar scores of less than 7 had pH values less than 7.20. Of 33 newborns, 9.1 percent who had Apgar scores of seven or more had pH of less than 7.20. We determined the sensitivity of the one minute Apgar score in acidemia to be 78 percent, the specifity to be 63 percent, the positive predictive value as 39 percent, and the negative predictive value as 90 percent. The one minute score is very poor for detecting acidosis when present but is rarely misleading when acidosis is absent.

There was a positive correlation between the Apgar score and pH ($p < 0.001$). The best correlation with umbilical artery pH values was observed with base excess (-BE) values ($p < 0.001$). Severe acidosis ($pH < 7.11$) was detected in eight cases. As ΔpH increases, pH, pO_2 and HCO_3 decrease and pCO_2 increases. Of 11 infants with $\Delta pH \geq 0.20$, 63.6 percent were sick infants and only one (9%) had normal Apgar scores. *Key words: Apgar score, umbilical cord blood gas, newborn, acidemia.*

The Apgar score was originally devised as a rapid and reproducible method for evaluation of an infant's condition at birth[1]. The Apgar score is not a specific indicator of birth asphyxia. In fact, newborn depression has many diverse causes, including maternal drug ingestion, trauma, neonatal manipulation, congenital anomaly, prenatal fetal insults, prematurity and, finally, birth asphyxia, which is a relatively minor contributor. Most authorities agree that it is extremely important to obtain umbilical cord blood pH samples in the presence of newborn depression since it will rule out birth asphyxia in approximately 80 percent of cases[2].

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In this study we aimed to demonstrate the relationship between Apgar scores and umbilical arterial blood gas values and to determine the importance of these values in fetal distress and asphyxia.

Material and Methods

The data for this report were derived from 61 newborns and their mothers in whom clinical characteristics were prospectively documented, and fetal and maternal blood gas and acid-base assessments were carried out at delivery.

The gestational ages of newborns ranged from 38 to 41 (39.3 ± 1.2) completed weeks with birth weights of 3022 ± 541 g. All newborns were appropriate for gestational age.

Blood gas and acid-base assessment of umbilical arterial blood was performed on blood drawn from a clamped segment of the umbilical cord obtained immediately after delivery. Maternal blood samples were taken from the antecubital vein.

All samples were obtained in the delivery room with pre-heparinized, 3-ml, plastic, sterile syringes with attached 1.5-inch, 22-gauge needles to obtain a consistent preparation and concentration of heparin. The analysis was performed within 15 minutes of delivery, using a blood gas analyzer (NOVA STAT PROFILE 1988) that measured pH, pCO_2, pO_2 and base deficit, hemoglobin (HB), hematocrit (Hct) and ΔpH calculated as maternal pH-umbilical arterial pH.

Apgar scores were determined by a pediatrician during the first and fifth minutes using a chronometer after vaginal delivery. In our study group, perinatal risk factors were as follows: meconium aspiration, cord prolapsus, preeclampsia-eclampsia, urinary tract infection, diabetes mellitus and smoking during pregnancy. The sick infants with meconium aspiration, two with cord prolapsus, and two with eclamptic and preeclamptic mothers. Only one newborn among the sick infants needed resuscitation, and the correlation between resuscitation and blood gasses could not been investigated.

Univariate analyses were performed with the student's t test. Data were analyzed with the unpaired student's test and linear regression analysis.

Results

Of 61 newborns, 28 had one-minute Apgar scores of less than seven, representing 45.9 percent of the births. Thirty-three newborns (54.1%) had Apgar scores of seven or greater. Umbilical arterial gas determinations of those groups are shown in Table I. There was no statistical difference between the gestational ages of these groups. The five-minute Apgar score was less than seven in four cases

(6.6%). While 14 (23%) of 61 newborns had pH values of less than 7.20, 47 (77%) had a pH of 7.20 or greater. The other parameters were also decreased, and the mean Apgar score was lower in the acidemic group than in the nonacidemic group. The values are displayed in Table II.

Table I: Umbilical Arterial Acid-Base Values and Mean Values of Hemoglobin, Hematocrit and ΔpH in Newborns with One-Minute Apgar Scores < 7 and > 7

Parameters	Apgar < 7 (n = 28)	Apgar ≥ 7 (n = 33)	p
pH	7.190 ± 0.132	7.287 ± 0.60	< 0.001
pCO_2	49.05 ± 7.64	45.14 ± 4.67	< 0.01
pO_2	15.86 ± 4.09	18.69 ± 3.34	< 0.001
HCO_3	17.44 ± 4.28	19.11 ± 3.10	< 0.05
BE	-9 ± 6.20	-5.32 ± 3.03	< 0.001
Hb	17.60 ± 1.58	16.60 ± 1.24	< 0.001
Hct	52.38 ± 5.45	49.49 ± 3.59	< 0.01
ΔpH	0.18 ± 0.09	0.13 ± 0.04	< 0.001

BE: Base excess. Hb: Hemoglobin. Hct: Hematocrit.

Table II: Mean Umbilical Arterial Acid-Base Values, Hemoglobin, Hematocrit and Apgar Scores in Newborns with Arterial pH ≥ 7.20 and < 7.20

Parameters	pH ≥ 7.20 (n = 47)	pH < 7.20 (n = 14)	p
pCO_2	44.72 ± 4.61	54.38 ± 6.35	< 0.001
pO_2	18.52 ± 3.41	13.62 ± 3.25	< 0.001
HCO_3	19.27 ± 2.98	15.25 ± 4.48	< 0.001
BE	-5.01 ± 2.29	-13.85 ± 5.97	< 0.001
Hb	16.75 ± 1.34	18.11 ± 1.49	< 0.001
Hct	49.72 ± 4.19	54.51 ± 4.67	< 0.001
ΔpH	0.12 ± 0.04	0.24 ± 0.10	< 0.001
One-minute Apgar score	6.7 ± 1.1	5.3 ± 2.1	< 0.01
Five-minute Apgar score	8.1 ± 1.6	7.8 ± 1.8	< 0.01

Only 39.3 percent (11 cases) of 28 newborns with one-minute Apgar scores of less than seven and 75 percent (3 cases) of four newborns with five-minute Apgar scores of less than seven had pH values of less than 7.20. Of 33 cases, 9.1 percent (3 cases) who had Apgar scores of seven or more had pHs of less than 7.20. There was a positive correlation between the Apgar score and pH ($p < 0.001$). This positive correlation with one-minute Apgar score of less than seven is shown in Figure 1, and the positive correlation in the group with umbilical arterial pH of less than 7.20 is shown in Figure 2.

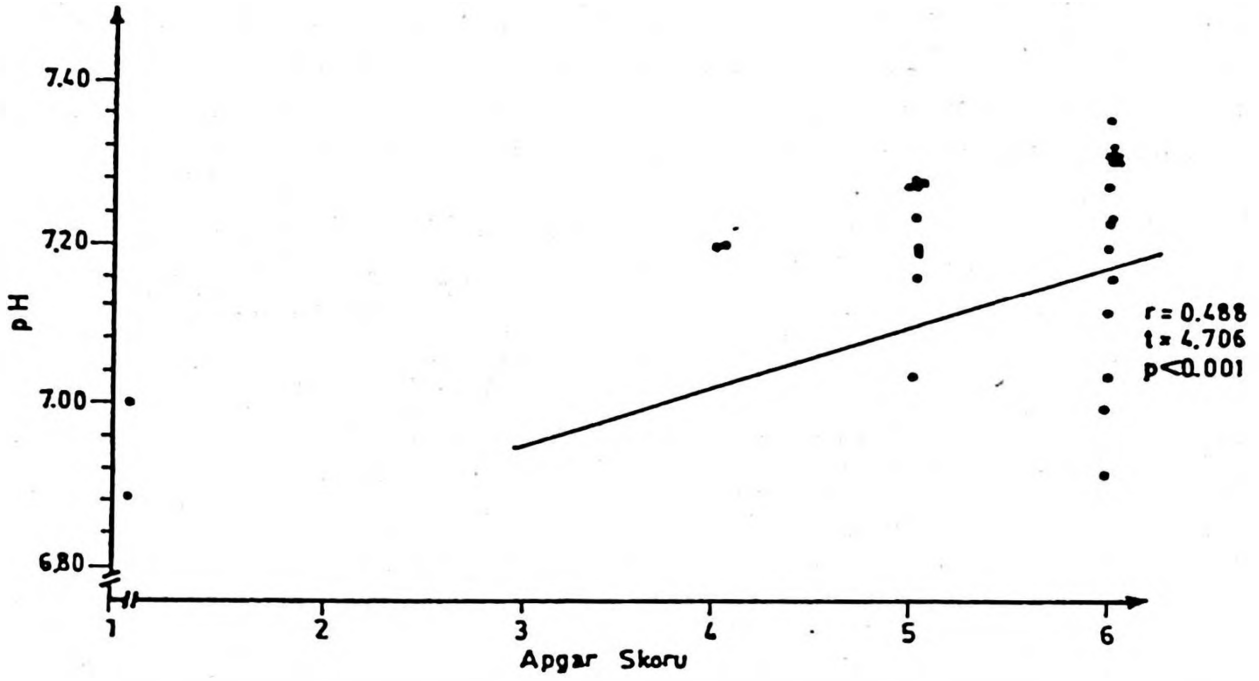

Fig. 1: The positive correlation between Apgar score and pH in newborns with one minute Apgar score < 7.

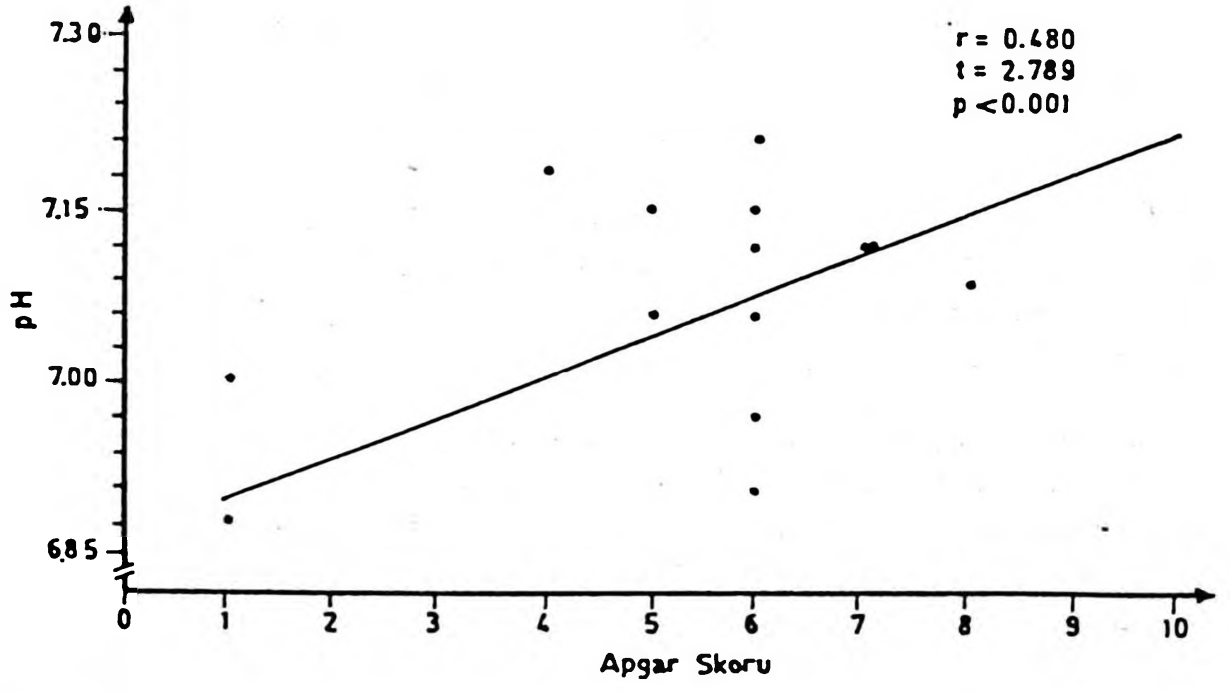

Fig. 2. The positive correlation between one minute Apgar score and pH in newborns with umbilical arterial pH < 7.20.

The best correlation with umbilical artery pH values was observed with base excess (-BE) values ($p < 0.001$). This correlation is shown in Figures 3 and 4.

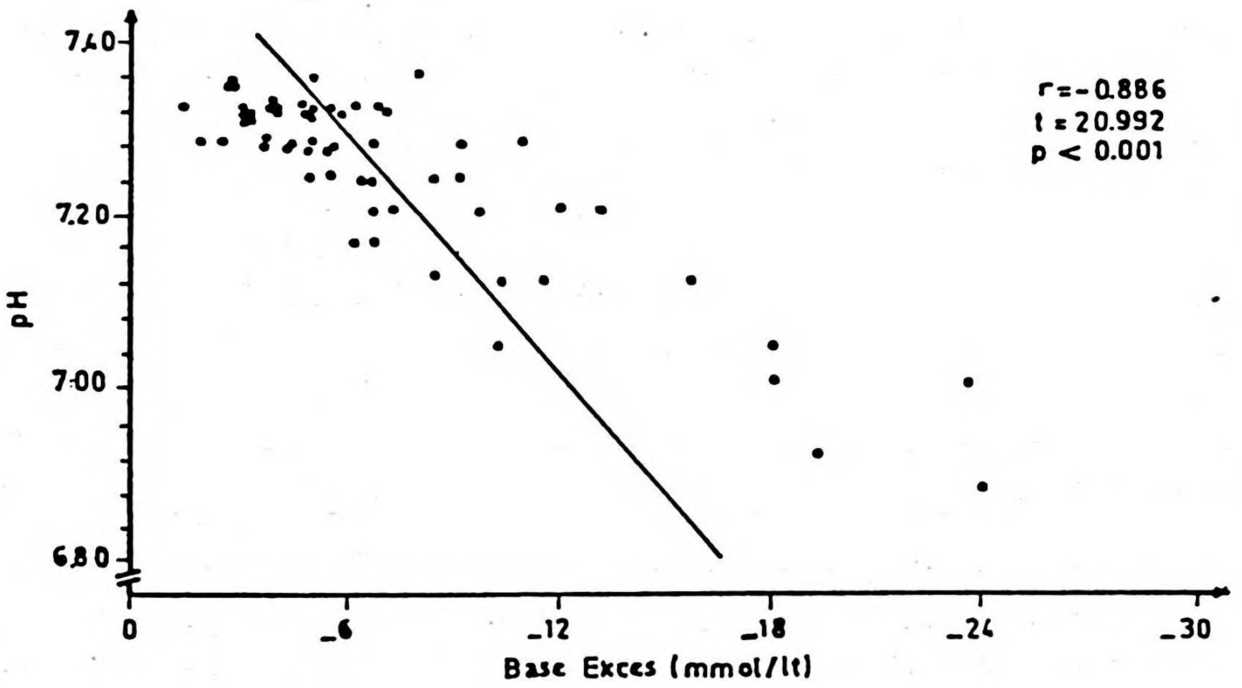

Fig. 3: The negative correlation between BE and pH in newborns with one minute Aapgar score < 7.

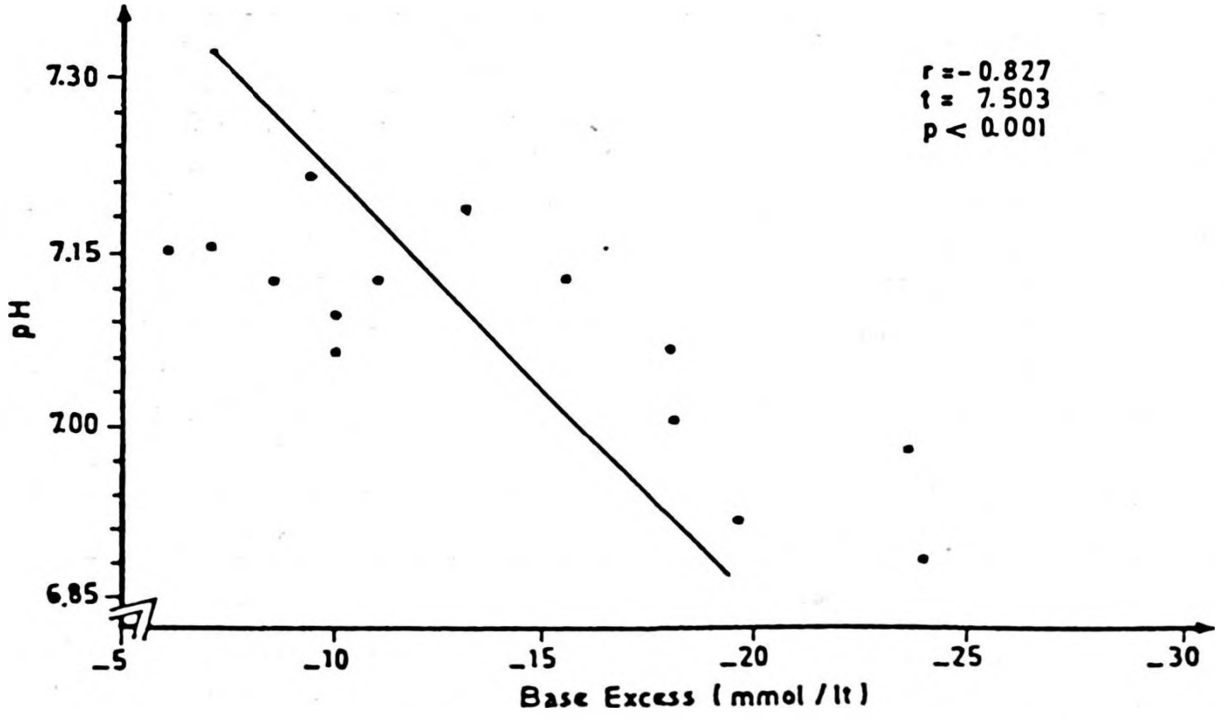

Fig. 4: The negative correlation between BE and pH in newborns with umbilical arterial pH < 7.20.

Severe acidosis (pH < 7.11) was detected in eight cases, as shown in Table III. The other parameters were observed to be correlated with the decreasing pH values.

Table III: Blood Gas Values, Mean ΔpH and Apgar Score of Newborns with Umbilical Arterial pH ≥ 7.11 and pH < 7.11

Parameters	pH ≥ 7.11 (n = 53)	pH < 7.11 (n = 8)	p
pCO_2	45.65 ± 5.46	55.42 ± 6.46	< 0.001
pO_2	17.88 ± 3.69	14.20 ± 4.26	< 0.01
HCO_3	19.25 ± 2.90	12.35 ± 3.29	< 0.001
BE	-5.48 ± 2.66	-17.36 ± 5.33	< 0.001
ΔpH	0.13 ± 0.04	0.27 ± 0.12	< 0.001
One-minute Apgar score	6.6 ± 1.2	5.0 ± 2.6	< 0.05
Five-minute Apgar score	7.9 ± 1.8	7.4 ± 2.2	< 0.05

According to ΔpH values, newborns were divided into three groups as less than 0.15, 0.15 to 0.19 and 0.20 or greater ΔpH. The arterial blood gas values and Apgar scores of these groups are shown in Table IV, and their statistical comparisons in Table V.

Table IV: Mean Values of Umbilical Arterial Acid-Base Values, Hemoglobin, Hematocrit and One-Minute Apgar Scores in Newborns with ΔpH < 0.15(A), ΔpH 0.15-0.19(B), ΔpH ≥ 0.20(C) and their Statistical Differences

Parameters	ΔpH < 0.15[a] (n = 40)	ΔpH: 0.15-0.19[b] (n = 10)	ΔpH ≥ 0.20[c] (n = 11)	a-b p	a-c p	b-c p
pH	7.29 ± 0.04	7.20 ± 0.09	7.08 ± 0.12	< 0.001	< 0.001	< 0.001
pCO_2	44.7 ± 5.44	49.22 ± 6.27	53.0 ± 5.86	< 0.01	< 0.001	> 0.05
pO_2	18.71 ± 3.54	16.20 ± 3.16	13.67 ± 3.41	< 0.01	< 0.001	< 0.05
HCO_3	19.12 ± 3.11	18.61 ± 4.03	15.26 ± 4.37	> 0.05	< 0.001	< 0.05
BE	-4.92 ± 2.11	-7.83 ± 5.20	-14.05 ± 6.36	< 0.05	< 0.001	< 0.05
HB	16.72 ± 1.43	17.45 ± 1.10	17.94 ± 1.62	< 0.05	< 0.01	> 0.05
Hct	49.64 ± 4.51	52.13 ± 3.37	53.93 ± 5.13	< 0.05	< 0.001	> 0.05
One minute Apgar score	6.8 ± 1.1	6.7 ± 0.8	4.6 ± 2.0	> 0.05	< 0.001	< 0.001
Five minute Apgar score	8.2 ± 1.3	7.6 ± 1.1	5.7 ± 1.9	< 0.05	< 0.001	< 0.001

As ΔpH increases, pH, pO_2 and HCO_3 decrease and pCO_2 increases. The negative correlation between ΔpH and umbilical artery pH ($p < 0.001$) and the negative correlation between one-minute Apgar scores and ΔpH are shown in Figures 5 and 6. Of the 11 infants (63.6%) with ΔpH ≥ 0.207, seven were sick infants and only one (9%) had normal Apgar scores.

Table V: Comparison of Acid-Base Values, Apgar Scores, ΔpH Values Between Groups with Perinatal Risk Factors and without Risk Factors

Parameters	With perinatal risk factor (n = 28)	Without perinatal risk factors (n = 33)	p
pH	7.201 ± 0.136	7.278 ± 0.067	< 0.001
pCO_2	48.13 ± 7.42	45.92 ± 5.45	> 0.05
PO_2	16.38 ± 4.33	18.25 ± 3.41	< 0.05
HCO_3	17.09 ± 4.35	19.41 ± 2.80	< 0.01
BE	-9.22 ± 6.43	-5.15 ± 2.40	< 0.001
ΔpH	0.18 ± 0.09	0.13 ± 0.04	< 0.001
One-minute Apgar score	5.9 ± 1.8	6.8 ± 1.0	< 0.01
Five-minute Apgar score	6.8 ± 1.7	8.2 ± 1.5	< 0.001

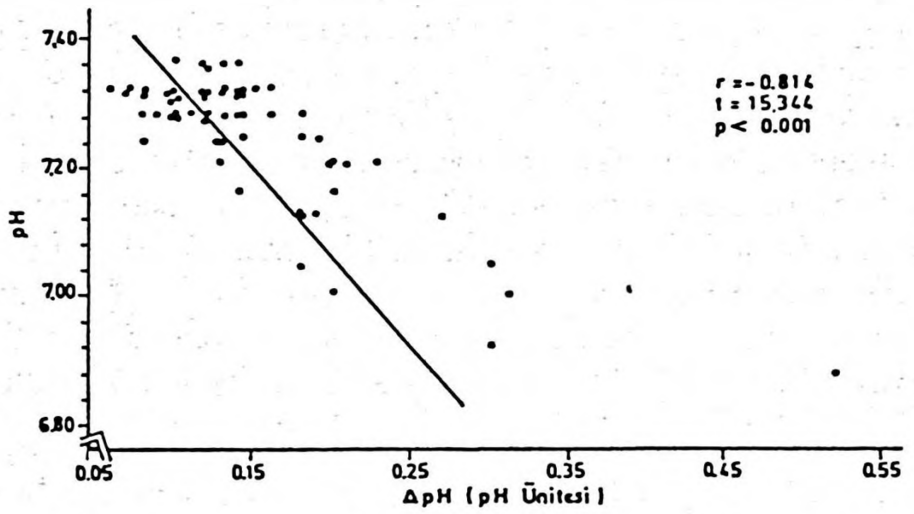

Fig. 5: The negative correlation between ΔpH and umbilical arterial pH.

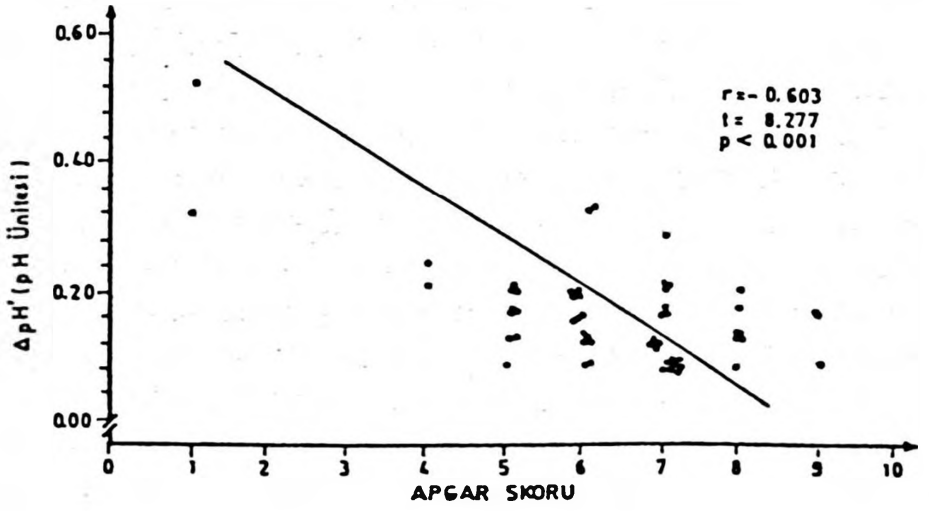

Fig. 6: The negative correlation between one minute Apgar score and ΔpH.

Discussion

The Apgar scores assigned at one and five minutes of age have long been used to define perinatal asphyxia, serve as a reference for other diagnostic tests, and attempt to prognosticate neonatal and later outcomes. Nevertheless, it has been well established that low Apgar scores are not synonymous with hypoxia, acidosis, or asphyxia[3]. Gestational age, maternal medications, infection, congenital disorders affecting the neuromuscular system, and neonatal cardiopulmonary condition at birth are but a few of the factors that can interfere with scoring. Improper scoring and inconsistency in scoring between observers must also be considered when interpreting Apgar scores[4].

Umbilical blood acid-base studies are objective measurements that can quantify the extent of fetal acidosis. The determination supplies information supplemental to the Apgar score in the evaluation of the neonate's condition[5]. Cord blood-gas measurements, obtained at the time of delivery in the case of a significant degree of metabolic acidosis, can indicate hypoxemia[5]. The absence of acidosis can exclude asphyxia in the presence of low Apgar scores and effectively shift the physician's attention to the identification of other possible causes of newborn depression. Preview data in the literature suggest that cord arterial pH is the most accurate reflection of fetal and newborn status when compared with all other cord arterial and venous blood-gas measurements[6,7]. The umbilical artery rather than vein has been used because the arterial values reflect tissue acid-base status while umbilical venous values reflect placental tissue acid-base status[8].

Many authors have demonstrated that cord arterial pH correlates best with Apgar scores[7,9-11]. We also detected a significant positive correlation between the first-minute Apgar scores and arterial pH values ($p < 0.001$) (Figs. 1, 2).

Sykes et al.[7] reviewed the relationship between Apgar score at one minute and cord arterial pH of less than or greater than 7.10. Only 27 percent of infants with a pH of less than 7.10 had one minute Apgar scores of less than seven (i.e., the Apgar score failed to identify severe acidosis in 73% of cases). On the other hand, only 21 percent of those with Apgar scores of less than seven at one minute had severe acidosis, and only 19 percent of infants with a five minute score of less than seven had severe acidosis. Boehm et al.[12] and Page et al.[10] reported the sensitivity of the one-minute Apgar score to be 78 and 46 percent, specificity 75 and 84 percent, positive predictive value 40 and 38 percent, and negative predictive value 94 and 88 percent, respectively. In our study, 28 newborns (45.9%) had one-minute Apgar scores of less than seven. pH values of less than 7.20 were detected in 14 (23%), and only 39.3 percent (11 cases) of 28 cases with Apgar scores of less than 7 had pH of less than 7.20 and in 9.1 percent (3 cases) of 33 cases who had Apgar scores greater had than seven

a pH of 7.20 or more. We determined the sensitivity of the Apgar score in acidemia to be 78 percent, the specificity to be 63 percent, the positive predictive value as 39 percent, and the negative predictive value as 90 percent. The one-minute score is very poor at detecting acidosis when present but is rarely misleading when acidosis is absent[13].

Cord, acid-base studies cannot distinguish whether fetal acidosis or alkalosis is the direct result of primary, fetal, pathologic conditions or the indirect result of maternal acid-base disorders. Maternal alkalosis secondary to hyperventilation can cause fetal hypocapnia and a rise in pH, which might obscure concurrent fetal metabolic acidosis[13].

The normal range of buffer base is 46-49 mEq/L. By definition, in nonpregnant women the normal base deficit or base excess equals 0 mEq/L. Actual calculations show the normal range of base excess to be -20 ± 1.0 mEq/L. During pregnancy, the mother hyperventilates and decreases her plasma bicarbonate but keeps her plasma pH constant. She also has a relative anemia and hypoproteinemia. In this setting, buffer base is depleted, creating a base deficit of 2-3 mEq/L. This can also be expressed as a base excess of -2 to -3 mEq/L[13].

In the presence of respiratory alkalosis, mild metabolic acidosis in an asphyxiated infant would not be detectable using cord pH measurements alone. If complete cord gas studies are obtained, metabolic acidosis would be apparent by the base deficit value. A less common acid-base disorder seen in laboring patients is metabolic acidosis resulting from the physical exertion of labor exacerbated by dehydration, infection or hypoglycemia. Fixed acids in the mother cross the placenta relatively slowly but can result in a harmless metabolic acidosis in the fetus in the absence of asphyxia. Fetal acidosis caused by the transfer of maternal fixed acids is usually characterized by minimal fetal base deficit[14]. A metabolic acidosis results in excess acid and a decreased buffer base. This is expressed as a negative base deficit or a base excess.

Gordon and Johnson[15] found the best correlation to pH with base excess. Goldenberg et al.[16] also stated that BE and HCO_3 are more important criteria for determining fetal acidemia than pH. Miller et al.[17] found a correlation between Apgar score, pH and BE. Silverman et al.[6] reported that a BE value of 10 mmol/L is more important than the Apgar score. Sykes et al.[7] determined severe acidemia (pH < 7.11) in newborns who had BE values greater than 12 mmol/L. We determined the best correlation to pH with -BE vlaues ($p < 0.001$), as shown in Figures 3, 4. Six of eight newborns who had BE of greater than 12 mmol/L (Table VI) had severe acidemia.

Another measure would be to determine the difference between maternal and fetal pH (usually measured on umbilical arterial blood). It has been reported that a difference in maternal-fetal pH of less than 0.15 units indicated maternal acidosis as the cause of fetal acidosis[18].

Table VI: Mean Acid-Base Values, Hemoglobin, Hematocrit ΔpH and One-Minute Apgar Scores in Sick and Healthy Newborns

Parameters	Sick newborns (n = 8)	Healthy newborns (n = 53)	p
pH	7.089 ± 0.025	7.266 ± 0.089	< 0.001
pCO_2	52.92 ± 5.73	46.03 ± 6.12	< 0.001
PO_2	13.37 ± 3.90	18.00 ± 3.60	< 0.001
HCO_3	14.312 ± 4.52	18.95 ± 3.25	< 0.001
BE	-14.93 ± 6.85	-5.85 ± 3.53	< 0.001
ΔpH	0.26 ± 0.11	0.14 ± 0.05	< 0.001
One-minute Apgar score	4.1 ± 2.2	6.7 ± 1.0	< 0.001
Five-minute Apgar score	5.4 ± 2.1	8.3 ± 1.4	< 0.001

Some authors have declared that ΔpH value is one of the most important criteria in the evaluation of the newborn at birth and estimating the neurological development in case maternal alkalosis is not present[18]. Rooth et al.[18] determined the mean ΔpH value in a group of newborns and their mothers without risk factors as 0.10 U, and as 0.15 U in the group with risk factors.

In our study the mean ΔpH was 0.15 ± 0.07 U. It was 0.18 ± 0.09 U in the group with risk factors and 0.13 ± 0.04 U in the normal group, and the statistical difference was significant ($p < 0.001$). The negative correlation between and umbilical artery pH ($p < 0.001$), and the negative correlation between the one-minute Apgar score and ΔpH are shown in Figures 5 and 6. The difference of 0.03 U in ΔpH between our study and the study of Rooth et al.[18] may be due to the applied anesthesia and analgesia to the mothers in their group to avoid hyperventilation during labor.

When we accept acidemia as ΔpH of greater than 0.20 (the same as Rooth et al.[18]), only one (9%) of 11 newborns with ΔpH values greater than 0.20 had one-minute Apgar scores of seven or greater. Seven of eight newborns in the sick group (87.5%) had ΔpH of 0.20 or greater while 62.5 percent of the eight sick newborns had pH of less than 7.20. Seven percent had one-minute Apgar scores of less than seven, and 87.5 percent had ΔpH values of 0.20 or greater. ΔpH values are more reliable than umbilical arterial pH and Apgar scores.

We conclude that in the evaluation of newborns and sick infants using Apgar scores and acid-base values in umbilical arterial blood (especially pH and base excess), evaluating the ΔpH by determining mothers' pH values is an appropriate method.

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