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Acid–Base Status in Diabetic Mothers and Their Infants Following General or Spinal Anesthesia for Cesarean Section

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Acid–base status was studied in 30 diabetic mothers and their infants and in 30 healthy mothers and their babies after general or spinal anesthesia for cesarean section. A normal acid–base state was found for the diabetic subjects following general anesthesia and for the healthy subjects following general or spinal anesthesia. However, the infants of diabetic mothers given spinal anesthesia had an average *p*H of 7.20 and a base excess value of −5.67 mEq/l in umbilical-artery blood at delivery. These values were significantly lower than those observed in the infants of the other groups, where the average *p*H was between 7.28 and 7.30 and the base excess between −1.87 mEq/l and 1.00 mEq/l. These findings were significantly related to maternal diabetes and maternal hypotension. (Key words: Anesthesia, obstetric; Anesthetic techniques, spinal; Acid–base equilibrium; Complications, diabetes, hypotension.)

DIABETES IN PREGNANCY is associated with increased maternal and fetal hazards, and a high incidence of elective delivery by cesarean section. There is evidence that where the disease is well controlled, normal acid–base values are found in both mother and baby following general anesthesia for elective cesarean section.[1,2] The present study compares the acid–base status of diabetic parturients and their babies after general anesthesia for cesarean delivery with that found in such patients following spinal anesthesia. Differences between these groups were significant.

Methods and Materials

Subjects of the study were 30 well-controlled, diabetic parturient patients; 15 received general anesthesia and the rest spinal anesthesia for elective cesarean section. Maternal diabetes was classified according to criteria developed by White.[3] A group of 30 healthy, nondiabetic women was similarly studied at the time of elective cesarean section. Fifteen of these parturients received spinal anesthesia, and 15, general anesthesia. Informed consent was obtained from each patient.

The choice of anesthesia was left to the mother. When she wanted to be awake, spinal anesthesia was selected, and when she preferred to be asleep, general anesthesia was used.

The anesthetic technique was the same in all cases once the type of anesthesia was selected. The patients were given atropine, 0.5 mg, intramuscularly, approximately an hour prior to anesthesia. Five per cent dextrose in lactated Ringer's solution, 1,000 ml, was administered intravenously within 15 to 30 minutes of induction. For spinal anesthesia, 1 per cent tetracaine, 8–9 mg, mixed with 0.8–0.9 ml of 10 per cent dextrose, was injected through a spinal needle. Oxygen, 5 l/min, was administered via a plastic disposable mask from the time of induction of spinal anesthesia until delivery of the baby. Sensory block to pinprick extended to T4 for most patients. For general anesthesia, patients were preoxygenated for several minutes. Thiopental, 4 mg/kg, followed by succinylcholine, 100 mg, was given intravenously for induction, and an endotracheal tube was inserted. Anesthesia was maintained by manual ventilation with nitrous oxide, 4 l/min, and oxygen, 2 l/min, from a standard adult circle anesthesia system. An intravenous infusion of succinylcholine, 0.1 per cent, in 5 per cent dextrose solution was used for muscle relaxation during the operation. A wedge was placed under the right side and hip of each patient to effect left uterine displacement.

The time from the start of the injection of the drug, either thiopental or tetracaine, to the completion of delivery was recorded in minutes as induction–delivery (I-D) interval.

Hypotension was defined as a decrease in maternal systolic blood pressure to below 100 torr or a decrease in systolic pressure of more than 30 torr from the baseline level. Blood pressure was determined by auscultation using a standard arm cuff connected to a mercury manometer. It was recorded at one-minute intervals from induction of anesthesia to delivery. Hypotension was treated promptly by intravenous administration of ephedrine, 10–20 mg. Additional ephedrine was given when hypotension persisted beyond a minute.

At the time of delivery, a sample of maternal venous blood was obtained from every patient. Maternal ar-

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TABLE 1. Characteristics of Population

	Healthy		Diabetic	
	General Anesthesia	Spinal Anesthesia	General Anesthesia	Spinal Anesthesia
Number of patients	15	15	15	15
Maternal age (years)	29 ± 1*	31 ± 1	30 ± 2	29 ± 1
Maternal height (inches)	63 ± 0.9	63 ± 0.7	62 ± 0.6	62 ± 0.5
Maternal weight (pounds)	150 ± 4	157 ± 7	143 ± 3	158 ± 11
Gestational age (weeks)	39 ± 0.2	40 ± 0.1	37 ± 0.4	38 ± 0.1
Class of diabetes (number)				
A			1	1
B			1	4
C			7	6
D			5	3
E			0	0
F			1	1
Maternal hypotension (number)	0	8	0	6
Induction to delivery interval (min)	7 ± 0.6	16 ± 0.9	8 ± 1.0	17 ± 1.6
Birth weights of babies (g)	3405 ± 113	3323 ± 126	2951 ± 151	3015 ± 81
Apgar scores				
1 min	8 (3–9)†	9 (7–9)	7 (4–9)	7 (4–9)
5 min	9 (8–10)	9 (9–10)	9 (7–10)	9 (6–10)

*Mean ± standard error.
† Median (range).

terial blood was collected from 24 of the 60 patients, six in each group. Samples of umbilical-artery and umbilical-vein blood were taken from a doubly clamped segment of umbilical cord at the time of delivery. The *p*H and oxygen and carbon dioxide partial pressures were determined directly from each blood sample with a Radiometer microelectrode system. Base excess for each sample was calculated from the Siggaard-Andersen nomogram.[4] Apgar scores at 1 and 5 minutes were determined by an independent observer, a pediatrician who was assigned to the care of infants in the delivery suite for that day.

Several statistical methods were used to measure the significance of the results.[5,6] The t test for unpaired data was applied to the difference between the major groups for population characteristics, acid–base and blood-gas values. It was also used to test the data for the spinal anesthesia groups subdivided into normotensive and hypotensive groups. Two-way analysis of variance was used to compare the acid–base data for all patients classified into groups according to diabetes, no diabetes, hypotension, and no hypotension.

Fisher's exact test was applied to fourfold tables divided according to the number of diabetic patients classified A through C and D through F versus: 1) number of these mothers with and without hypotension prior to delivery, 2) type of anesthesia, general or spinal, and 3) number of babies with low Apgar scores (less than 7) and high Apgar scores (7 or better) at 1 minute. Yates chi square was applied to fourfold tables divided according to numbers of high and low Apgar scores at 1 minute versus number of infants with *p*H less than 7.25 or 7.25 or more in umbilical-artery blood.

Multiple correlation coefficients and significance tests were computed from patient characteristics and acid–base and blood-gas data for the various groups.

Results

All diabetic parturients except those with Class A diabetes were hospitalized one week or more prior to delivery for the purpose of controlling the disease. Most of these mothers had their infants delivered before 40 weeks' gestation, and these infants weighed less at birth than the infants of the healthy mothers (table 1).

The numbers of diabetic mothers in the various classifications were comparable in the general and spinal anesthesia groups. Systolic blood pressure did not exceed 130 torr in any diabetic mother within 24 hours of operation. Maternal hypotension was observed in six diabetic mothers and in eight healthy parturients following spinal anesthesia (table 1). There was no significant relationship between severity of diabetes and incidence of maternal hypotension. Hypotension was frequently associated with symptoms of dizziness and nausea, but did not last longer than three minutes in any case.

The acid–base statuses of the mothers in all four groups were normal at delivery (table 2).

The infants of diabetic mothers given spinal anesthesia had significantly lower average *p*H values in umbilical-artery and umbilical-vein blood (table 2) at birth compared with babies of diabetic mothers given general anesthesia ($P = 0.002$ and $P = 0.03$). Base excess was also significantly lower and P_{CO_2} higher in umbilical-artery blood (table 2) of babies of diabetic mothers who received spinal anesthesia ($P < 0.001$ and $P = 0.002$). A significant correlation was found when *p*H values in the bloods of infants in the spinal anesthesia group were plotted against the severity of maternal diabetes, *i.e.*, the lower the *p*H the more severe the maternal diabetes ($r = 0.614$, $P < 0.025$). There was no significant difference between infants of diabetic mothers given general anesthesia and infants of healthy mothers given general anesthesia in terms of the acid–base and blood-gas statuses of blood taken from the umbilical artery.

With regard to the spinal anesthesia groups (table 3), the lowest *p*H and base excess values among these groups were found in infants of diabetic mothers in whom hypotension developed prior to delivery. Comparisons of *p*H and base excess data in blood samples obtained from umbilical arteries of all infants (table 4) also revealed that the values were significantly less in cases where either maternal diabetes or maternal hypotension had been present, and that maternal diabetes and hypotension, together, were associated with the worst neonatal acid–base status.

TABLE 2. Acid–Base and Blood-gas Data

Sample Site	Healthy		Diabetic	
	General Anesthesia	Spinal Anesthesia	General Anesthesia	Spinal Anesthesia
Maternal vein				
*p*H	7.42 ± 0.01*	7.38 ± 0.01	7.42 ± 0.02	7.38 ± 0.01
Maternal artery				
*p*H	7.46 ± 0.02	7.43 ± 0.02	7.43 ± 0.01	7.43 ± 0.01
P_{O_2} (torr)	177 ± 12	218 ± 9	193 ± 24	209 ± 7
P_{CO_2} (torr)	33 ± 1	34 ± 4	32 ± 1	33 ± 1
BE (mEq/l)	+0.58 ± 0.90	−0.67 ± 0.68	−0.10 ± 0.41	−0.86 ± 0.56
Umbilical vein				
*p*H	7.38 ± 0.01	7.34 ± 0.01	7.34 ± 0.01	7.29 ± 0.02
P_{O_2} (torr)	32 ± 2	37 ± 3	34 ± 3	30 ± 2
P_{CO_2} (torr)	41 ± 1	48 ± 2	47 ± 2	52 ± 2
Umbilical artery				
*p*H	7.30 ± 0.01	7.28 ± 0.01	7.29 ± 0.01	7.20 ± 0.02
P_{O_2} (torr)	18 ± 2	18 ± 1	24 ± 3	18 ± 2
P_{CO_2} (torr)	56 ± 2	63 ± 2	61 ± 2	67 ± 2
BE (mEq/l)	−1.87 ± 0.73	−1.40 ± 0.82	−1.00 ± 0.66	−5.67 ± 0.98
Maternal artery BE minus umbilical artery BE (Δ base deficit)	0.58 ± 0.25	1.00 ± 0.86	1.10 ± 0.46	4.14 ± 1.01

* Mean ± standard error.

TABLE 3. Acid–Base and Blood-gas Data for Infants of Mothers Who Received Spinal Anesthesia

Sample Site	Healthy		Diabetic	
	No Hypotension	Hypotension	No Hypotension	Hypotension
Umbilical vein				
*p*H	7.35 ± 0.01*	7.34 ± 0.01	7.30 ± 0.01	7.26 ± 0.03
P_{O_2} (torr)	37 ± 3	38 ± 4	32 ± 2	25 ± 2
P_{CO_2} (torr)	50 ± 3	46 ± 2	52 ± 2	51 ± 4
Umbilical artery				
*p*H	7.30 ± 0.01	7.26 ± 0.01	7.24 ± 0.02	7.15 ± 0.03
P_{O_2} (torr)	20 ± 2	16 ± 2	19 ± 2	16 ± 2
P_{CO_2} (torr)	63 ± 1	63 ± 3	65 ± 3	71 ± 4
BE (mEq/l)	0.43 ± 1.01	−3.00 ± 0.94	−4.35 ± 0.88	−8.25 ± 1.74

* Mean ± standard error.

TABLE 4. Two-way Classifications and Significances for Mean *p*H and Base Excess Values in Umbilical-artery Blood by Factors of Hypotension and Diabetes

	No Diabetes	Diabetes	Total	Source of Variation	*P*
*p*H					
No hypotension	7.30	7.27	7.29	Between no hypotension/hypotension groups	<0.001
Hypotension	7.26	7.15	7.20	Between no diabetes/diabetes groups	<0.001
TOTAL	7.28	7.21	7.24	Hypotension × diabetes interaction	0.010
Base excess					
No hypotension	−1.14	−2.23	−1.68	Between no hypotension/hypotension groups	<0.001
Hypotension	−3.00	−8.25	−5.62	Between no diabetes/diabetes groups	<0.004
TOTAL	−2.07	−5.24	−3.65	Hypotension × diabetes interaction	0.05

Only two infants of healthy mothers had Apgar scores less than 7 at one minute, while 14 of the 30 infants of diabetic mothers had lower scores, six in the general anesthesia group and eight in the spinal anesthesia group (table 5). A significant relationship was found between the incidence of low Apgar scores at one minute and the number of infants with *p*H values lower than 7.25 in blood from the umbilical artery ($P < 0.05$). Four of the infants of diabetic mothers given spinal anesthesia and two of the infants of diabetic mothers given general anesthesia required intermittent positive-pressure ventilation with oxygen via bag and mask. None of these babies needed more than two minutes of assisted ventilation. There was no instance of meconium in the amniotic fluid at delivery. Three of the infants of diabetic mothers had mild respiratory distress syndrome. Two of these babies were in the spinal anesthesia group and one was in the general anesthesia group. All infants were eventually discharged in good health.

Discussion

With regard to the acid–base and blood-gas statuses of healthy subjects who received general or spinal anesthesia for elective cesarean section, our study supports the findings of Marx *et al.*[7] In the absence of maternal hypotension, there was no significant difference between parturients who received general anesthesia and those given spinal anesthesia. However, when hypotension occurred after spinal anesthesia there was a lower *p*H and less base excess, especially in umbilical-artery blood. The incidence of maternal hypotension after spinal anesthesia was high in our population of healthy parturients (53 per cent) despite rapid hydration and the use of left lateral tilt. However, the hypotension was corrected with ephedrine, and none of the infants of healthy mothers given spinal anesthesia had an Apgar score below 7 at one minute.

Our study also confirms findings in previous investigations[1,2] with respect to the acid–base state in diabetic mothers and their infants following general anesthesia for cesarean section. The acid–base and blood-gas values of the diabetic mothers and their infants did not differ remarkably from those observed in healthy mothers and their infants after general anesthesia for cesarean section, *i.e.*, acid–base status was normal in these subjects. However, in our study, 40 per cent of infants of diabetic mothers given general anesthesia had Apgar scores below 7 at one minute, compared with 13 per cent of the infants of healthy mothers given general anesthesia. It is possible that the less mature infants of diabetic mothers were more profoundly depressed by general anesthetics or subject to more trauma at delivery than term infants.

The primary aim of our study was to compare the acid–base status of diabetic mothers and their infants after general anesthesia with that found in such patients after spinal anesthesia. There was no attempt to randomize the choice of anesthetic technique, since it was not feasible in our clinical population. This may have introduced an element of bias of indeterminate magnitude. However, in every case the diabetes was well controlled, and the numbers of diabetic mothers in the various classifications were comparable in the general and spinal anesthesia groups. There was also no significant difference in gestational ages or birth weights between the two groups.

We found the acid–base statuses of infants in these two groups to be significantly different. Infants of diabetic mothers given spinal anesthesia had significantly lower *p*H values and less base excess in blood obtained from the umbilical artery compared with infants of diabetic mothers given general anesthesia. This mild

TABLE 5. Numbers of Apgar Scores Less Than 7 at 1 and 5 Minutes

	Healthy		Diabetic	
	General Anesthesia (n = 15)	Spinal Anesthesia (n = 15)	General Anesthesia (n = 15)	Spinal Anesthesia (n = 15)
1 minute	2	0	6	8
5 minutes	0	0	0	1

acidosis appeared to be related to both maternal diabetes and maternal hypotension.

One can only speculate about the possible mechanisms responsible for these findings. Maternal hypotension is known to decrease uteroplacental blood flow, while maternal diabetes is associated with placental abnormalities even in the case of mild, well-controlled gestational diabetes.[8] The combination of these conditions may have altered the placental exchange of oxygen, carbon dioxide and fixed acids, resulting in the mild acidosis observed in infants of diabetic mothers given spinal anesthesia. Although the blood-gas values did not reflect marked impairment of placental exchange, it is possible that once the maternal hypotension was corrected, uteroplacental perfusion improved, leading to more normal acid–base and blood-gas status in the baby.

Another aspect should be considered. It has been shown in sheep that the placenta does have the capacity to produce lactate.[9] There is also evidence that, *in vitro*, glycogenolysis occurs in the placenta and is enhanced in a hypoxic environment.[10] This might bring about higher concentrations of lactate and a decreased *p*H in the fetus. Such a mechanism would be more likely to occur in diabetic parturients, since diabetes is associated with increased glycogen content of the placenta.[3]

Finally, Shelley *et al.*[11] found that when plasma glucose was increased to more than 40 mg/100 ml in a slightly hypoxic lamb fetus, there was a rapid increase in plasma lactate with a decrease in *p*H during the period of hyperglycemia. We have observed plasma glucose levels in excess of 100 mg/100 ml in umbilical cord blood of infants of diabetic mothers following rapid hydration with 5 per cent dextrose in lactated Ringer's solution. Perhaps, in our study, the infants of diabetic mothers given spinal anesthesia became slightly hypoxic during maternal hypotension, and in the presence of hyperglycemia, mild acidosis developed.

The high incidence (53 per cent) of low Apgar scores at one minute in infants of diabetic mothers given spinal anesthesia may have occurred because these babies were not at term and hence were more susceptible to the effects of the delivery process. On the other hand, it may indicate some depression due to mild asphyxia.

In conclusion, our study suggests that, in the case of healthy parturients undergoing elective cesarean section, spinal anesthesia associated with hypotension may result in less base excess and a lower *p*H in the baby, in comparison with general anesthesia. However, when the hypotension is rapidly corrected, little if any neonatal depression can be observed. Balanced general anesthesia does not appear to be related to significant alterations in acid–base status of healthy or diabetic mothers and their infants. However, spinal anesthesia given to diabetic parturients is associated with mild acidosis in the newborn. The acidosis appears to be related to both maternal diabetes and maternal hypotension.

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