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Neonatal Pattern of Breathing Following Cesarean Section: *Epidural* versus *General Anesthesia*

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We tested the hypothesis that different anesthetic techniques for elective cesarean section would be reflected in the pattern of breathing and its control after birth. The pattern of breathing, including tidal volume, total breath duration (T_{TOT}), minute ventilation, inspiratory (T_I) and expiratory times, T_I/T_{TOT} ratio, and mouth occlusion pressure, was measured in 27 infants delivered by elective cesarean section during maternal epidural (lidocaine-carbon dioxide-epinephrine, n = 19) or general anesthesia (66% oxygen in N_2O and 0.5% halothane, n = 8) at 10, 60, and 90 min and 3–5 days of age. Neonatal acid-base values and Apgar scores were within normal limits in both groups of infants. In general, at any given age the values of the respiratory parameters measured and their variability were similar between the two groups of infants. These findings indicate that the pattern of breathing after birth is not different following epidural or general anesthesia, and on the basis of our measurements, both epidural or general anesthesia appeared equally suitable for elective cesarean section. (Key words: Anesthesia: obstetrics. Anesthetic techniques: epidural. Ventilation: anesthetics, effects of.)

COMPARISONS OF FETAL OUTCOME following cesarean section delivery employing different anesthetic techniques such as epidural or general anesthesia often have been made on the basis of Apgar scores, blood gas values, and time to sustained respiration.[1–3] Recently, it has been found these variables lack the sensitivity to detect subtle changes in the neurologic status of the newborn following the administration of analgesics and anesthetics to the mother.[4–6] Since anesthetic agents exert an influence on the pattern of breathing,[7–9] we felt this also might be true to varying degrees in infants delivered by cesarean section during different anesthesia techniques.

The purpose of the present study was to compare the components of the respiratory pattern as well as mouth occlusion pressure (which is a mechanical index of respiratory drive[10]) in infants delivered by cesarean section during maternal epidural or general anesthesia.

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Materials and Methods

CLINICAL PROTOCOL

Studies were conducted on 27 infants in operating rooms and nurseries. The study was approved by the hospital ethics committee and informed written consent obtained from each mother. All patients were ASA Physical Status I, having elective repeat cesarean section. The mothers were given the choice of either epidural (n = 19) or general anesthesia (n = 8), and both groups had similar age, weight, and caffeine intakes. The anesthetic technique was the same as that previously described.[3] Premedication in both groups was atropine 0.4 mg im and 30 ml antacid (30 ml 0.3 M sodium citrate by mouth) preoperatively.

In the epidural group, an epidural catheter was inserted in the lumbar region, the patient placed in the supine position, and a wedge inserted under the right hip. Following prehydration with 1,000 ml Ringer's lactate, sensory analgesia to T4 was achieved by injecting lidocaine-carbon dioxide (1.86%) with epinephrine (1/200,000). Intravenous ephedrine was used to treat maternal hypotension (systolic blood pressure < 100 mmHg). Patients received 100% oxygen to breathe by mask for at least 10 min before delivery.

Patients given general anesthesia were positioned similarly to the epidural group and received 100% oxygen to breathe for at least 3 min prior to induction of anesthesia. After the patient was prepped and draped, anesthesia was induced with intravenous 2.5% thiopentone (3–4 mg/kg) followed by succinylcholine (1 mg/kg) and endotracheal intubation. Respiration was controlled[3] so that maternal carbon dioxide tensions were unchanged with respect to the preanaesthetized state. Anesthesia was maintained by 33% nitrous oxide and 0.5% halothane in oxygen from induction to delivery of the baby.

At delivery, umbilical vein and artery blood samples were taken from a doubly clamped section of cord. Induction to delivery (I-D) and uterine incision to delivery (U-D) intervals were recorded. One- and five-minute Apgar scores were assigned by the attending pediatrician.

EXPERIMENTAL PROTOCOL

The recording apparatus was similar to that previously described[11] and consisted of a rubber mask, fitted with a Fleisch pneumotachograph and a port for sampling

TABLE 1. Body Weights, Blood Gases, Time Intervals, and Apgar Scores at Birth (Mean and Standard Deviation)

	Anesthesia	
	Epidural	General
Birth weight (kg)	3.4 ± 0.4	3.5 ± 0.4
Umbilical vein		
P_{O_2} (mmHg)	33 ± 7	37 ± 11
*p*H	7.37 ± 0.03	7.35 ± 0.03
P_{CO_2} (mmHg)	37 ± 4	40 ± 3
Base deficit (mEq/l)	3 ± 3	3 ± 2
Umbilical artery		
P_{O_2} (mmHg)	19 ± 4	24 ± 3*
*p*H	7.31 ± 0.03	7.34 ± 0.03*
P_{CO_2} (mmHg)	47 ± 4	43 ± 4*
Base deficit (mEq/l)	4 ± 2	3 ± 3
Intervals		
I-D† interval (min)	27.2 ± 7.0	5.6 ± 0.8*
U-D‡ interval (s)	74 ± 39	70 ± 40
Apgar score: number of infants <7		
1 min	1	0
5 min	0	0
n	17	8

* $P < 0.05$.
† I-D = Induction to delivery interval.
‡ U-D = Uterine incision to delivery interval.

mouth pressure. This was placed over the nose and mouth of the infant. Total dead space of the apparatus was 10.0 ml and the flow resistance was 0.93 $kPa \cdot l^{-1} \cdot s$ (9.45 cm $H_2O \cdot l^{-1} \cdot s$). Air flow, its integral tidal volume, and mouth pressure were recorded on a pen recorder for monitoring during the recording procedure and on a four-channel Hewlett-Packard tape recorder for later playback and analysis.

Recordings were obtained at 10, 60, and 90 min after delivery. Eight infants also were studied at 3–5 days of age. Recordings at 10 min were obtained with the infants in an incubator, while the other measurements were made with the babies wrapped in blankets in their cots. The mask was placed on the baby's face, and when the infant was resting quietly, recordings were made for 5–10 min, during which mouth occlusions were performed by manually occluding the outlet of the pneumotachograph. No measurements were made if the infant had eyes open, gross body movements, or was crying. The infants were quiet and appeared to be sleeping, although no attempts were made to define further the state of arousal.

DATA ANALYSIS

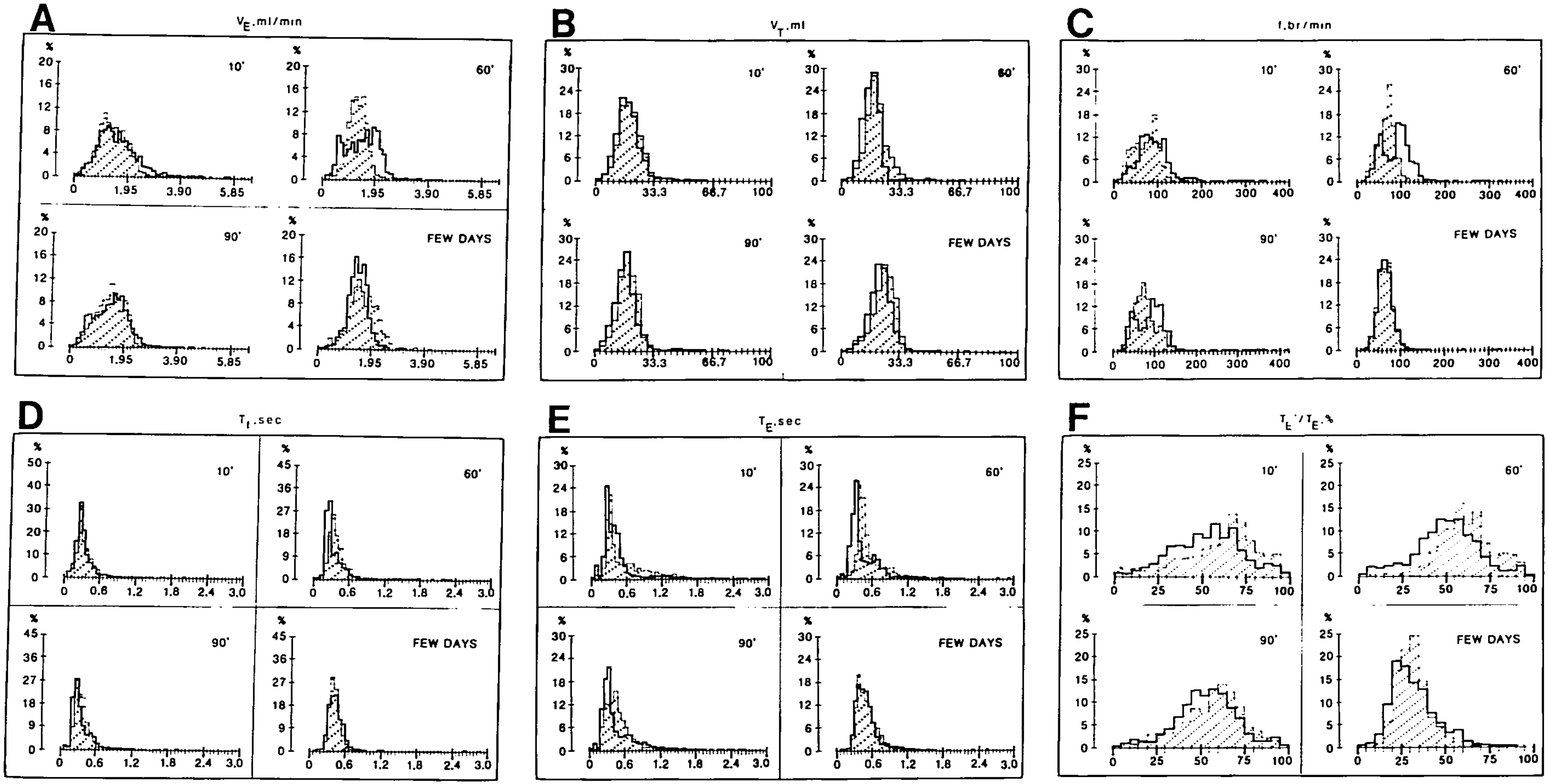
Records were digitized manually with a graphic tablet and stored on tape for statistical analysis and graphic representation of spirometric variables by a mini-computer (HP85). In addition to the standard respiratory variables (tidal volume, V_T; respiratory rate, f, and its reciprocal, T_{TOT}; minute ventilation, $\dot{V}_E$; inspiratory, T_I; and expiratory time, T_E) the time after the onset of expiration at which peak expiratory flow occurred (T'_E) also was measured and expressed as a percentage of T_E ($T'_E/T_E \times 100$). The mean number of breaths analyzed in each baby was 138 breaths at 10 min after delivery, 191 breaths at 60 min, 188 at 90 min, and 210 at a few days of age.

For each record, the coefficient of variation (CV) was calculated from the mean $\bar{x}$ and standard deviation (SD) according to the formula CV = SD/$\bar{x}$% in order to assess the variability of respiratory components at different times after birth. Because the mean is affected by outlying observations, the mode has been calculated to illustrate the values for each respiratory variable that were most common in each group of infants. A *t* test for unpaired data was performed to detect differences of the average modal values and coefficients of variation between the two groups of infants for the variables measured at different times after birth. A statistically significant difference was defined by a $P < 0.05$ for a two-tailed test. Goodness of fit of normal distributions was verified with a chi-square test ($P < 0.05$).

Results

Table 1 presents the values of blood gases, time intervals, and Apgar scores for the two groups of infants. Significant differences were observed between the two methods for the umbilical artery blood gases and the induction to delivery intervals.

Histograms of $\dot{V}_E$, V_T, and f (upper panels), and T_i, T_E, and the time peak of expiratory flow (T'_E) expressed as percentage of T_E (lower panels) at 10, 60, and 90 min and a few days after birth are presented in figure 1 for the infants of each of the two anesthesia groups. The histograms were constructed from all the breaths analyzed for the infants in each anesthesia group at the different times after birth. The total number of breaths analyzed ranges from 1,500–2,500 breaths at each time period in the epidural group and 1,000–2,000 in the general anesthesia group of infants. In general, the frequency histogram distribution of the respiratory variables measured overlapped considerably, and there were no differences for most of the values obtained at each time interval between the two anesthesia groups (fig. 1 and table 2). There was a statistical difference between the two groups at 60 min and a few days of age for V_T (larger in the general anaesthesia group), and at 10 min after birth the general anesthesia group T'_E/T_E ratio was statistically larger and the T_I/T_{TOT} smaller than the values for the epidural infants. The variability of the respiratory parameters measured in each group, represented by the coefficients of variation, were not different at any time interval after birth (table 3). This also is reflected in figure 1 by the similar width (or scatter) of the frequency histograms. Mouth occlusion pressure values ($P_{0.1}$) were similar for infants delivered during maternal epidural or general anesthesia (table 2) at each time interval after birth.



FIGS. 1*A–C*. Frequency histograms of minute ventilation ($\dot{V}_E$), tidal volume (V_T), and respiratory frequency (f) at 10, 60, and 90 min and a few days after birth, of all the breaths analyzed for infants delivered during maternal epidural anesthesia (open columns, thick lines) or general anesthesia (dotted columns, thin lines). In general, there were no differences between the distribution of the respiratory values of either group of infants. The exception was V_T at 60 min and a few days of age. *D–F*. Frequency histograms of inspiratory time (T_I), expiratory time (T_E), and time after the onset of expiration at which peak expiratory flow occurred expressed as a percentage of T_E ($T_E'/T_E \times 100$) at 10, 60, and 90 min and a few days after birth. Values for the epidural and general anesthesia group were not different except for T_E'/T_E and T_I/T_{TOT} at 10 min of age.

TABLE 2. Average Model Values ($\bar{x}$) and Standard Deviations (SD) of Respiratory Variables after Birth for Infants Delivered during Maternal Epidural (EP) or General (GA) Anesthesia

Time after Birth	$\dot{V}_E$ (ml/min)		V_T (ml)		f (breaths/min)		T_I (s)		T_E (s)		T_{TOT} (s)		T_E'/T_E (%)		T_I/T_{TOT}		$P_{0.1}$ (kPa)	
	EP	GA	EP	GA	EP	GA	EP	GA	EP	GA	EP	GA	EP	GA	EP	GA	EP	GA
10 min																		
$\bar{x}$	1,491	1,495	17.4	18.1	91	84	0.32	0.32	0.33	0.39	0.65	0.72	57	69*	0.48	0.41*	0.60	0.58
SD	500	461	4.6	4.2	18	23	0.08	0.07	0.08	0.13	0.15	0.18	14	5	0.06	0.11	0.21	0.39
n	15	8	15	8	15	8	15	8	15	8	15	8	12	8	15	8	6	2
60 min																		
$\bar{x}$	1,446	1,341	16.4	22.0*	90	67	0.32	0.36	0.39	0.57	0.72	0.90	51	67	0.46	0.42	0.45	0.36
SD	529	190	3.7	3.8	27	15	0.09	0.03	0.17	0.31	0.25	0.17	7	16	0.03	0.06	0.16	0.10
n	8	4	8	4	8	4	8	4	8	3	8	4	6	3	8	4	5	2
90 min																		
$\bar{x}$	1,365	1,453	18.3	19.9	86	77	0.34	0.36	0.45	0.46	0.80	0.78	56	62	0.45	0.45	0.40	0.36
SD	518	432	4.1	4.9	32	20	0.12	0.07	0.23	0.14	0.35	0.20	12	8	0.07	0.05	0.15	0.10
n	15	7	15	7	15	7	15	7	15	7	15	7	14	7	15	7	8	6
3–5 days																		
$\bar{x}$	1,495	1,723	22.5	28.4*	68	64	0.44	0.44	0.48	0.48	0.87	0.90	30	29	0.48	0.5	0.42	0.36
SD	150	358	2.5	3.8	12	10	0.08	0.06	0.08	0.10	0.11	0.14	5	4	0.06	0.03	0.16	0.09
n	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4

Abbreviations: $\dot{V}_E$ = minute ventilation; V_T = tidal volume; f = respiratory frequency; T_I = inspiratory time; T_E = expiratory time; T_{TOT} = total breath duration; T_E'/T_E = time after onset of expiration of peak expiratory flow expressed as a percentage of T_E.

There are no significant differences between the respiratory variables of the two groups infants except for V_T at 60 min and a few days of age and T_E'/T_E and T_I/T_{TOT} at 10 min of age (* $P < 0.05$).

1 kPa = approx. 10 cmH_2O.

TABLE 3. Mean Values of the Coefficients of Variation (%) of Respiratory Variables after Birth for Infants Delivered during Maternal Epidural (EP) or General (GA) Anesthesia

Time after Birth	$\dot{V}_E$		V_T		f		T_I		T_E		T_{TOT}		T_E'/T_E		T_I/T_{TOT}	
	EP	GA	EP	GA	EP	GA	EP	GA	EP	GA	EP	GA	EP	GA	EP	GA
10 min																
$\bar{x}$	36	39	32	37	33	40	43	47	77	75	56	52	34	36	27	31
n	15	8	14	8	15	8	15	8	15	8	15	8	12	8	15	8
60 min																
$\bar{x}$	28	28	29	32	24	24	34	41	55	38	44	30	34	23	22	22
n	8	4	8	4	8	4	8	4	8	4	8	4	6	3	8	4
90 min																
$\bar{x}$	29	26	30	29	26	21	28	28	45	49	31	33	30	29	19	17
n	15	7	15	7	15	7	15	7	15	7	15	7	14	7	15	7
3–5 days																
$\bar{x}$	25	26	25	24	27	27	27	25	38	32	27	24	37	31	15	14
n	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4

See table 1 for definitions of abbreviations. There were no differences between the coefficients of variation of the two groups of infants ($P > 0.05$).

Discussion

In general, the two groups of infants appeared to be similar (table 1). The small differences in umbilical artery blood gases resemble previous trends.[3] However, the values are all within the normal limits and are not considered to be clinically significant. The above measurements, however, are not very sensitive indicators of the infant's neurologic status, and the results of neonatal neurobehavioural tests have suggested that the type of anesthetic or analgesic employed in either vaginal[4,12] or cesarean section deliveries[5,13,14] may have effects on the newborn that last several hours after birth.

Our original hypothesis was that an examination of the timing and volume components of the respiratory pattern, as well as the mouth occlusion pressure (thought to some extent to reflect respiratory drive[10]), might reveal differences not shown by other techniques between infants delivered during maternal epidural or general anesthesia. However, most of the variables measured showed no difference between the two groups of infants. The difference between the two groups of infants for V_T at 60 min and 3–5 days of age and for T_I/T_{TOT} at 10 min were small considering the variability of these values in each infant (table 3), although they did reach statistical significance. The absence of a meaningful physiologic difference also is supported by the finding of similar T_I and T_{TOT} values at 10 min, while the difference between V_T at 3–5 days of age most likely reflects the small sample size at this age. Furthermore, the decrease in the variability of the timing components of respiration (*i.e.*, T_{TOT}, T_I, T_E) that occurs from 10 min to a few days of age after birth[11] was not affected by the type of anesthesia employed.

Both groups of infants delayed peak expiratory flow until late in expiration (last one-third of T_E) in the immediate period after birth (fig. 1 and table 3), and the values of T'_E/T_E overlapped considerably, although there was a tendency for the general anesthesia group to delay peak flow more than the epidural group at 10 min. The use of laryngeal adductors and the delay of peak expiratory flow until late in expiration have been suggested to be strategies employed by the newborn infant to elevate or defend the end-expiratory volume.[11,15,16] However, to our knowledge, there is no evidence suggesting that the general anesthesia group of infants are in greater need to protect end-expiratory volume.

Quantitative measurements of the respiratory pattern at birth could be a method not sensitive enough to assess subtle differences in the well being of the newborn baby. In fact, the high variability at the onset of breathing and the respiratory adaptation in the first hours after birth is well documented.[16,17] However, it seems reasonable to suppose that clinically important differences would have been revealed and that possible trends masked by the variability would be practically irrelevant.

In conclusion, the lack of a difference in the respiratory pattern suggests that both epidural or general anesthesia are equally suitable as an anesthetic technique for elective cesarean section.

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