Comparison of Spontaneous and Controlled Breathing During Cyclopropane Anesthesia in Infants

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Clinical experience has demonstrated that the best way to maintain light surgical anesthesia with cyclopropane in infants, while avoiding exhaustion and cardiovascular disturbances, is to employ a controlled hyperventilation technique. Measurements of end-tidal P_{CO_2}, tidal volume and minute volume in a group of infants under three months of age indicate that spontaneous breathing during cyclopropane anesthesia provides effective ventilation for short periods. By employing four rate and pressure combinations of controlled breathing, all of which produced better pulmonary ventilation than present during spontaneous breathing, most effective hyperventilation was achieved at a moderate rate of about 40 per minute with a pressure of about 30 cm. of water. A change in airway pressure was noted to alter end-tidal P_{CO_2} more than a change in ventilatory rate, at the combinations measured.

PULMONARY VENTILATION is a crucial aspect of anesthesia for small infants. Most controversy in the field of ventilatory management of the anesthetized infant has arisen out of the related techniques of tracheal intubation and controlled breathing.[1,2] Since tracheal intubation now is almost universally accepted as an effective technique, even in these very small patients, we believed that the question of the control of breathing once the trachea is intubated merited further study.

The following study compares end-tidal P_{CO_2}, tidal volume and minute volume in a group of anesthetized infants during spontaneous breathing and during controlled ventilation at four different conditions of rate and pressure.

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Method

The subjects of this study were 12 infants, under 13 pounds in body weight below three months of age, who required operation for hernia or imperforate anus. Each was given 0.15 mg. atropine intramuscularly one hour before the beginning of anesthesia. Anesthetic induction was accomplished with a 1.5 to 2.0 liter flow of 40 per cent cyclopropane in oxygen, and ventilatory control was established and continued for about five minutes to obtain satisfactory relaxation for tracheal intubation. The adaptor to a tight-fitting tube was connected to a 90 g. Waters canister, and a pneumotachograph inserted between the canister and a 2-liter rebreathing bag (fig. 1). Cyclopropane, 200 ml./minute, and oxygen, 400 ml./minute were introduced through the tail of the bag. Carbon dioxide was sampled continuously from within the endotracheal tube adaptor and measured with an infrared carbon dioxide analyzer. Airway pressure was measured with an aneroid manometer placed at the proximal end of the canister. Excess gas was emptied from the system intermittently by dumping the bag during periods of end-tidal gas sampling.

After these preparations were completed, spontaneous breathing was allowed to return. Anesthesia was maintained at a surgical level using cyclopropane with oxygen. End-tidal P_{CO_2}, airway pressure and pneumotachograph tracings were recorded on a Grass polygraph. Respirations then were controlled at rate and pressure combinations which included rates of 40 and 80 per minute and pressures of 20 and 30 cm. of water. After each set of conditions had been established for a period sufficient to achieve stabilized measurements, the infant was allowed once more to breathe spontaneously.

Tidal volumes were calculated by integrat-

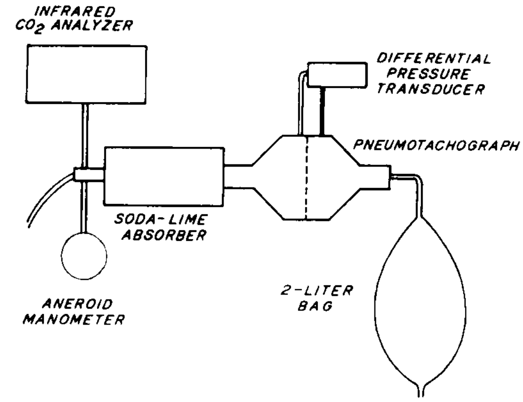

FIGURE 1.

ing the area under the expiratory portion of the pneumotachograph tracing. Corrections were made for the gas withdrawn during the continuous carbon dioxide analysis. End-tidal P_{CO_2} was determined by observing the plateau of the expiratory tracing. During rapid ventilation, manual control was halted for several seconds until a plateau occurred. Data were analyzed by the method of analysis of variance.[3]

Results

The results are summarized in table 1. During spontaneous breathing in light surgical anesthesia, the average end-tidal P_{CO_2} of the 12 infants was 37 mm. of mercury, the mean tidal volume was 33 ml., the mean rate was 45 breaths per minute, and the mean minute volume was 1.2 liters.

All four conditions of controlled breathing chosen in this study increased ventilation significantly compared to spontaneous breathing. In addition, a comparison between the two pressures and rates of ventilatory control yielded the following information. Independent of rate, an increase in airway pressure from 20 to 30 cm. of water caused a 6 mm. of mercury decrease in end-tidal P_{CO_2} ($P < 0.001$), a 16 ml. increase in tidal volume ($P < 0.001$), and a 900 ml. per minute increase of the minute volume ($P < 0.001$). A decrease in ventilatory rate from 80 to 40 per minute, irrespective of pressure, resulted in a significant increase in tidal and minute volumes ($P < 0.001$ and $P < 0.001$, respectively) but no significant change in end-tidal P_{CO_2}.

Discussion

Spontaneous breathing of infants in light surgical anesthesia with cyclopropane is surprisingly effective by adult standards for short periods. However, we have noted that infants breathing in this manner for any length of time tend to become exhausted and exhibit changes in heart rate and rhythm. Others have demonstrated in adults that the end-tidal P_{CO_2} eventually does rise with continued spontaneous breathing during cyclopropane anesthesia.[4] The abnormalities of heart rate and rhythm which occur in infants can be reversed by assisted or controlled hyperventilation, but even Smith,[2] an enthusiastic proponent of assisted respirations, agrees that ventilatory assist is difficult to accomplish in infants because of the normally rapid rate and small tidal volume. Clinically, the best way to insure evenness of anesthetic depth and avoid exhaustion and cardiovascular disturbances during cyclopropane anesthesia in small infants has been by using ventilatory control to the point of hyperventilation.

This study has shown that the most efficient way to produce a low end-tidal P_{CO_2} and a large tidal volume is to ventilate the lungs of infants at a moderate rate of about 40 per minute with a pressure of about 30 cm. of water. Prior to this study it had been our practice to hyperventilate infants more vigorously. There were no adverse clinical effects evident at these low levels of carbon dioxide tension. Blood pressure and pulse remained stable, there were no cardiac arrhythmias by auscultation, the color of the blood was satisfactory, and the patients all awakened within 15 minutes of the discontinuance of cyclopropane.

Richards and Bachman[5] have shown that in apneic paralyzed infants the inflation volume for a given pressure is greater after a higher pressure than following a smaller pressure. It is desirable, therefore, to punctuate controlled ventilation of any pressure magnitude in infants with periodic artificial hyperinflations several times a minute.

We have often seen infants with respiratory difficulty owing to atelectasis improve after

TABLE 1. Comparison of Spontaneous and Controlled Breathing During Cyclopropane Anesthesia in Infants

			P_{CO_2}, mm. Hg					Tidal Volume, ml.					Minute Volume, Liters				
			Spont.	Controlled				Spont.	Controlled				Spont.	Controlled			
				R =40/min.		R =80/min.			R =40/min.		R =80/min.			R =40/min.		R =80/min.	
No.	Age	Wt., lb.-oz.		20 cm. H_2O	30 cm. H_2O	20 cm. H_2O	30 cm. H_2O		20 cm. H_2O	30 cm. H_2O	20 cm. H_2O	30 cm. H_2O		20 cm. H_2O	30 cm. H_2O	20 cm. H_2O	30 cm. H_2O
A	9 W	10–12	27	25	18	20	20	35	55	63	40	46	2.2	2.4	2.5	3.2	3.7
B	4 W	8–7	43	21	23	21	17	28	34	41	20	29	1.3	1.4	1.6	1.6	2.3
C	3 M	13	35	27	18	27	25	32	58	81	34	61	0.8	2.1	3.3	3.0	5.3
D	11 W	10–7	46	35	28	37	23	44	56	68	25	67	1.0	1.7	2.8	2.0	4.8
E	8 W	9–5	44	29	34	30	20	44	45	60	44	43	1.3	1.8	2.2	3.8	3.4
F	6 W	7–10	43	33	21	30	20	23	25	64	29	39	1.0	1.0	2.5	2.3	3.1
G	3 M	10–8	38	23	21	22	14	22	46	64	39	56	0.8	1.8	2.6	3.1	4.5
H	8 W	10–7	38	30	15	32	18	30	31	56	34	58	1.4	1.2	2.2	2.7	4.6
I	9 W	11	36	28	25	27	25	40	54	70	35	60	—	2.0	2.4	2.4	3.6
J	2 M	11–10	32	30	24	21	23	43	38	50	32	48	—	1.4	2.0	2.6	4.7
K	6 W	9–8	25	29	23	26	16	20	45	48	35	46	—	1.8	2.2	2.8	3.7
L	8 W	8–1	—	28	25	29	28	—	38	47	31	35	—	1.4	1.8	2.6	2.8
Mean			37	28	23	27	21	33	44	59	33	49	1.2	1.7	2.3	2.7	3.9
S.D.			7	4	5	5	4	9	11	11	7	12	0.5	0.4	0.5	0.6	0.9

anesthesia in which controlled ventilation was used. We never have seen pulmonary edema or rupture of the lung occur secondary to overdistention caused by controlled ventilation either in a premature or full term infant.

Summary

End-tidal P_{CO_2}, tidal volume and minute volume have been measured in 12 infants anesthetized with cyclopropane during spontaneous breathing and four conditions of manually controlled ventilation. Optimum hyperventilation occurred at a controlled rate of 40 per minute and a pressure of 30 cm. of water. Increasing the rate to 80 per minute or decreasing the pressure to 20 cm. of water caused a decrease in tidal volume, but an increase in end-tidal P_{CO_2} occurred only with the change in pressure, although even under these conditions the infants were hyperventilated. Controlled breathing, to provide hyperventilation, is recommended for infants during cyclopropane anesthesia.

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