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Mechanical Ventilation of Newborn Infants I. The Effect of Rate and Pressure on Arterial Oxygenation of Infants with Respiratory Distress Syndrome

PENELOPE CAVE SMITH[33], WILLIAM J. R. DAILY, GRANT FLETCHER, H. BELTON P. MEYER and GORDON TAYLOR

Department of Pediatrics and Human Development, Center for Premature Infants, and the Department of Anesthesia, Stanford University School of Medicine, Stanford, California, USA

Extract

This study reports the effect of varying specific parameters of mechanical ventilation on aortic PO_2 in six infants with severe respiratory distress syndrome. Twenty-seven studies were performed during the first 168 hours of mechanical ventilation. In each study, arterial oxygen partial pressure was found to vary directly with airway pressure and inversely with respiratory rate. No correlation was found between rate and pressure, or PaO_2, $PaCO_2$, and pHa. Oxygenation of infants with severe respiratory distress syndrome can be significantly influenced by variation of specific parameters of mechanical ventilation independently of change in aortic carbon dioxide tension.

Speculation

Optimal oxygenation during mechanical ventilation of infants with severe respiratory distress syndrome is dependent upon selection of the specific and appropriate pattern of ventilation.

Introduction

A number of authors have reported the effects of mechanical ventilation when used in infants with respiratory distress syndrome (RDS) [2, 3, 8, 9, 10, 11, 19, 22, 25, 26, 28]. The opinion of most has been that mechanical ventilation corrects respiratory acidosis and may improve survival. To date, only one study describing the effects of varying specific parameters of mechanical ventilation in infants has been published [16].

The present report documents the changes in arterial oxygenation in six infants with severe RDS when respiratory rate and airway pressure were varied systematically during intermittent positive pressure ventilation (inspiratory) (IPPV/I).

Materials and Methods

Diagnosis and Care

The diagnosis of RDS in the infants studied was based on the presence of grunting, nasal flaring, and sternal retraction, together with a chest radiograph showing reticulo-granularity and an air bronchogram.

Infants were cared for in servo-regulated incubators set to maintain a skin temperature of 36 to 36.8° [29]. The concentration of warmed, humidified oxygen was

kept between 70 and 100 %. All infants received a continuous infusion of 5 % dextrose in water (65 ml/kg/24 h) via an umbilical arterial catheter, which was also used for sampling arterial (aortic) blood. An effort was made to maintain arterial pH above 7.30 [20] by intermittent intra-arterial administration of small doses of sodium bicarbonate and by intermittent manual ventilation using a one-liter bag and an infant mask with a seven-liter flow of 100 % oxygen. The latter procedure was performed for a maximum of five minutes every fifteen minutes. Intramuscular injections of penicillin (10,000 U/kg) and Kanamycin (7.5 mg/kg) were given every twelve hours.

Selection of Infants for Mechanical Ventilation

The effectiveness of this therapy was judged by scoring the infants by use of the criteria outlined in table I. Mechanical ventilation was begun when an infant's total score was 3 or more despite therapy with oxygen, sodium bicarbonate, and intermittent manual ventilation for a minimum of twelve hours. Six consecutive infants who met these criteria were studied.

Management

Intubation and initiation of mechanical ventilation were carried out as outlined previously [28]. We considered adequate alveolar ventilation had been obtained when $PaCO_2$ was between 30 and 40 mm Hg. During IPPV/I, the position of the infants was changed hourly, and percussion and drainage of the chest with suctioning of the airway via the endotracheal tube was performed [23]. For feeding and for prevention of regurgitation and aspiration, gastrostomy was performed after 12 to 48 hours of mechanical ventilation [7].

Table I. Criteria for selection of infants for mechanical ventilation

Score parameters	Score 0	Score 1	Score 2	Score 3
PaO_2 (in 100 % O_2)	> 70	50–70	40–49	< 40.0
pHa ($\bar{p}$ $NaHCO_3$)	7.31–7.50	7.20–7.30	7.00–7.19	< 7.0
$PaCO_2$	< 60	60–70	71–80	> 80.0 Apnea

For admission to the study, an infant had to score three or more following at least 12 hours of treatment with sodium bicarbonate, oxygen, and intermittent manual ventilation.

Ventilators

Two types of positive pressure ventilators having identical compressible volumes were used, a modified Harvard small animal respiration pump and a Bennett PR2. Both incorporated a minimum dead space circle, < 2.0 ml, with a heated humidifier on the inspiratory side. Tubing and humidifiers were replaced with sterile components every eight hours.

Initial Setting of Ventilator

The pressure and rate selected at the initiation of ventilation were such that the infant did not attempt to breathe (controlled ventilation). A fixed inspiration to expiration ratio of 1:1 was used. Arterial (aortic) pH, PO_2, and PCO_2 were measured 10 minutes after control of ventilation had been achieved. Adjustments of rate and pressure were then made until a pHa between 7.35 and 7.50 and a $PaCO_2$ between 30 and 40 mm Hg were obtained. Alveolar ventilation was then considered adequate.

Study

Sequence of Changes in Rate and Pressure

Four concomitant changes of rate and pressure were used to determine the effect of these on arterial oxygen tension (table II). Each pair of changes was based on the immediately preceding settings of the ventilator. The pairs of settings were selected to approximate similar levels of alveolar ventilation. Each pair of changes was given a number (1 to 4); the numbers were randomized, and a card was drawn for each study to give the sequence to be followed. In some studies, additional changes in rate and pressure were subsequently made to encompass a greater range or to bring alveolar ventilation or arterial oxygenation within a more acceptable range.

Recording of Rate and Pressure

Peak airway pressure was measured by using a stiff, polyethylene catheter connected to a 19-gauge needle that was inserted into the inspiratory limb of the respi-

Table II. Rate–Pressure changes

Parameters changed	Rate strokes/min	Pressure cm H_2O
No.		
1	+20	—10
2	+10	— 5
3	—10	+ 5
4	—20	+10

rator near the endotracheal tube. The catheter was connected to a Statham PM5 strain gauge, and the pressure curve was recorded on a Brush direct-writing oscillograph. Respiratory rate and end-inspiratory peak pressure were directly measured from these recordings.

End inspiratory flow rates of both ventilators were less than 0.1 l/s. Previous studies using endotracheal tubes of 3.5 mm I.D. or larger have shown that at such flow rates, the end inspiratory pressure in the ventilator tubing is essentially equal to the intratracheal pressure [5].

Blood Gas and pH Determination

Samples of arterial blood were drawn into Tomac heparinized 1 ml plastic syringes that were immediately sealed with mercury-filled caps, mixed, and placed in ice. Samples were analyzed for pH, PCO_2, and PO_2 within 15 minutes. Corrections of pH, $PaCO_2$, and PaO_2 were made to accommodate differences between the temperature of the electrode (38°) and the rectal temperature of the infant [21].

Estimation of Arterial Oxygen Content

Arterial oxygen saturation (SaO_2) was determined from measurements of PaO_2, pHa, and temperature as described by SEVERINGHAUS [21] and by KERNOHAN and FORSTER [12]. A pH unit of 0.20 was added to the pHa to adjust the difference in the effect of pH on the oxyhemoglobin dissociation curve of fetal hemoglobin [14]. Oxygen carried by hemoglobin ($CHbO_2$) was calculated from the infant's hemoglobin and SaO_2 ($CHbO_2 = SaO_2 \times$ Hb concentration $\times$ 1.34). Arterial oxygen content (CaO_2) was determined by adding dissolved oxygen ($PaO_2 \times 0.0031$) to $CHbO_2$. In some instances, total 'physiologic' right to left shunt was calculated according to the method of OWEN-THOMAS *et al.* [16].

Analysis of Data

Twenty-seven studies were performed on six infants considered to have disease of equal severity at the time of initiation of controlled ventilation (table III). The studies were grouped according to the time after initiation of ventilation: 0–12; 12–24; 24–48; 48–72; 72–120 and 120–168 hours. Changes in rate and pressure were analyzed in relation to the associated direction and magnitude of change in PaO_2, $PaCO_2$, and pHa.

Statistical Methods

Statistical analysis of the relations between rate and pressure (controlled variables) and PaO_2, $PaCO_2$, and pHa (dependent variables) was based on the Pearson product moment correlation coefficient. For each of the studies, these coefficients were computed between the controlled and the dependent variables, both for original values and for successive differences. The individual correlation coefficients, most of which were not significantly different from zero, were based on three to seven observations. In the case of successive differences, the usual 't' test for testing a correlation coefficient could not be applied because of dependence of the differences. In order to combine the results for the individual studies, 'sign tests' were applied to the 27 correlation coefficients obtained from the original measurements. The sign test was used because each of the sample correlation coefficients has a probability

Table III. Preventilation infant data

Infant	Sex	Birth weight g	Time of blood sampling (min before mechanical ventilation)	Age at initiation of mechanical ventilation h	Blood gas values and score prior to initiation of mechanical ventilation					Outcome
					PaO_2	$PaCO_2$	pHa	Other	Score	
LA	M	2240	15	59	25	60	7.31	–	4	D[1]
MO	F	2100	15	20	34	–	7.35	–	3	D
MT	F	2400	1	27	39	55	7.34	–	3	S[2]
FU	M	2080	5	35	–	98	7.07	apnea	8	S
RO	F	1800	3	16	60	70	7.26	apnea	6	S
OK	M	2400	10	41	35	–	7.25	apnea	7	S
Mean		2170	8.2	33	38.6	70.8	7.26			

[1] Died
[2] Survived

of 0.5 of being positive, if the variables are basically uncorrelated (irrespective of the number of observations per study). Consequently, a positive correlation between pressure and PaO_2 and a negative correlation between rate and PaO_2 were found ($p < 0.01$ in each case).

The study was designed to keep $PaCO_2$ relatively constant. To achieve this result, an increase in pressure was combined with a decrease in rate and *vice versa* (median for correlation coefficient was −0.87). There was, therefore, little independent variation between rate and pressure, and it was impossible to associate a variation in PaO_2 with either of the controlled variables alone.

Results

A positive correlation was found between an increase in PaO_2 and the combination of a decrease in rate and an increase in airway pressure. This relation between PaO_2 and specific parameters of IPPV/I was apparent in each group of studies. The effect was least prominent between 0–12 hours and most prominent between 12–48 hours (figs. 1–6). No correlation was found between absolute rate or absolute pressure and $PaCO_2$ or pHa; or between pHa or $PaCO_2$ and PaO_2 (appendices I–III). The range of absolute pressures used was 18–56 cm H_2O, and the range of absolute rates used was 14–70/min.

The absolute amount that PaO_2 would be expected to increase or decrease per unit change of rate or presture under the circumstances of this study is shown in table IV.

Table IV. Average change in PaO_2 per change of one unit in rate (bpm)[1] or pressure (cm H_2O) F_{IO_2}[2] = > 0.96

Duration of mech. vent. (h)	Number of studies	PaO_2 change per unit change in pressure	PaO_2 change[3] per unit change in rate
0– 12	4	+1.05	—0.76
12– 24	3	+5.88	—3.01
24– 48	6	+5.75	—2.98
48– 72	6	+4.07	—1.60
72–120	5	+1.61	—0.89
120–168	3	+2.08	—0.62

[1] Breaths per minute.
[2] Fraction O_2 in inspired gas.
[3] Change is expressed as mm Hg PaO_2 per cm H_2O or per breath per minute (6 separate study intervals).

Improved oxygenation, whether calculated as a rise in PaO_2, a rise in arterial oxygen content, or a decrease in estimated total right to left shunt (appendix III), occurred in each study employing the combination of an increase in airway pressure and a decrease in respiratory rate.

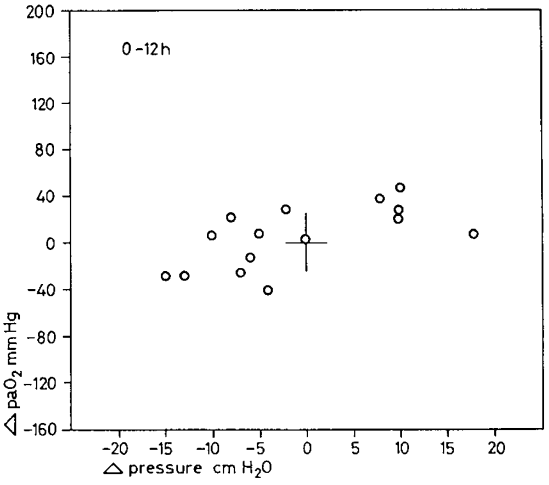

Fig. 1

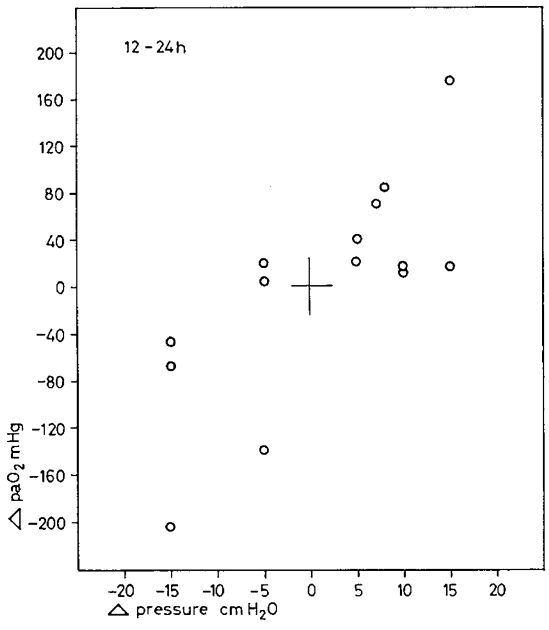

Fig. 2

Figs. 1–6. Relations between peak airway pressure and PaO_2, expressed as change from the value obtained at the immediately preceding ventilator settings. Each figure shows the points obtained within a specific time interval after initiation of mechanical ventilation.

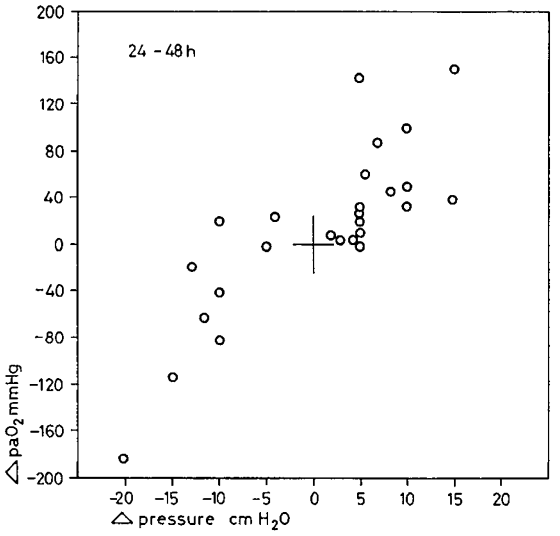

Fig. 3

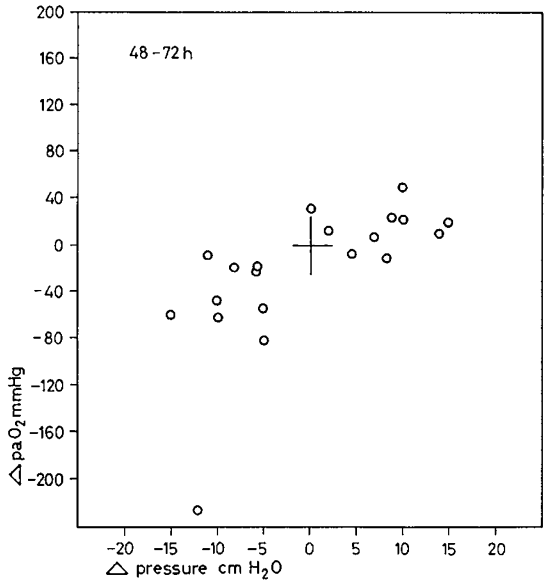

Fig. 4

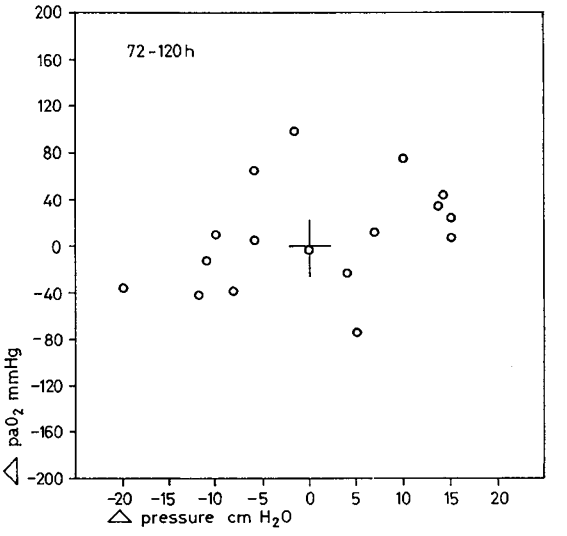

Fig. 5

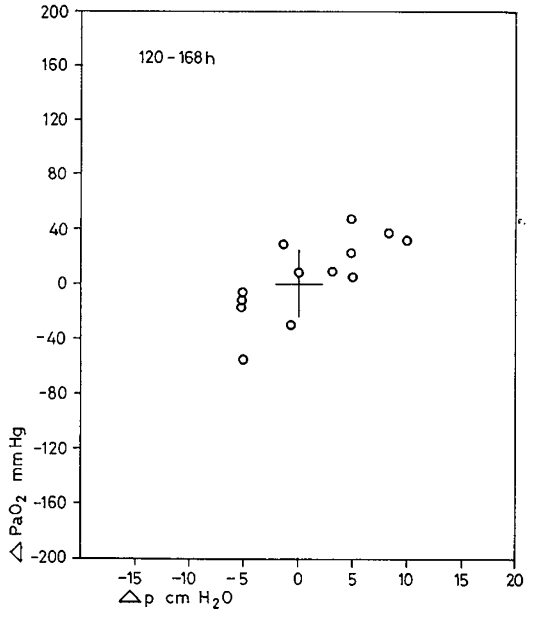

Fig. 6

Four of the six infants in this study survived. To date, at ages 16–19 months, neurological development is considered normal in each infant. Two infants (M.T. and O.K.) have no evidence of residual pulmonary disease. One infant (F.U.) has had slowly clearing clinical and radiological lung disease, and one infant (R.O.) has severe, chronic lung disease with cardiac failure.

Discussion

Many infants with RDS have been ventilated mechanically, but only one report documents a physiological change occurring as a result of specific variation of individual parameters of ventilation [16]. In that instance, improved oxygenation (increased PO_2 and decreased right to left shunting) was reported to be

associated with higher inspiratory flow rates and alteration of the inspiration:expiration ratio. All infants were studied at relatively high respiratory rates (60–70 bpm) at a fixed tidal volume of 10 ml/kg; airway pressures were not reported. Alveolar ventilation was not constant.

In the present study, adequate alveolar ventilation ($PaCO_2$) could be achieved over a wide range of rates and pressures. No differences were discerned between the responses of infants ventilated with a volume-regulated Harvard ventilator and those ventilated with a pressure-regulated Bennett PR2 ventilator. The changes in oxygenation reported occurred at a fixed inspiration:expiration ratio of 1:1; rate and pressure were varied without any significant alteration of $PaCO_2$. Thus, the pattern of mechanical ventilation influenced either the overall ventilation-perfusion ratio ($\dot{V}A/\dot{Q}$) or the overall pattern of effective perfusion of the lung *per se*. Although this effect was evident in every infant at each study, the mechanism(s) by which oxygenation was changed cannot be established from our data.

The previously reported tendency for individual infants to respond to a different degree to changes in specific parameters of ventilation at different ages [16] is also apparent in our study (figs. 1–6); however, the average magnitude of change in PaO_2 was greater in our infants than in those reported by OWEN-THOMAS *et al.* [16].

The lungs of infants with RDS are hyperperfused and often hypoventilated [6, 17, 18]. No significant impairment of diffusion has been demonstrated [15]. The observed arterial hypoxemia is due either to overall right to left shunting of blood through anatomical channels, venous admixture, and/or to continued perfusion of hypoventilated or unventilated lung (uneven $\dot{V}A/\dot{Q}$). Such shunting (hypoxemia) may increase with pulmonary vasoconstriction caused by acidosis or hypercarbia [20].

During the present study, arterial pH and CO_2 tensions were most often in the normal or alkalotic range; thus, the changes observed in oxygenation cannot be ascribed to changes in pulmonary vasoconstriction related to acidosis or hypercarbia. Increase in arterial oxygen tension occurred when the respiratory rate was decreased and the airway pressure was increased, while the inspired oxygen concentration and the inspiration:expiration ratio was not changed. Therefore, the changes in arterial oxygen tension must have been related to changes in total right to left shunt. The most likely explanation of this observation is that the pattern of artificial ventilation (slower rates and higher airway pressures or larger tidal volumes) resulted in more nearly normal overall ventilation-perfusion relations within the lung. Similar relations have been demonstrated both in animals [13] and in adult man [1].

The observation that the pattern of IPPV/I significantly influences oxygenation of infants with RDS does not define the underlying cause(s) of hypoxemia. It suggests, however, that in infants with severe RDS who are mechanically ventilated, changes in the pattern of IPPV/I may improve oxygenation without a change in ventilation ($PaCO_2$). Recovery from other deficiencies such as decreased surfactant activity and pulmonary vasoconstriction might thus be permitted and the chance for survival improved.

Our presumption that the infants selected for mechanical ventilation would have an extremely high mortality rate is supported by the observations of others [4, 9, 24]. We believe that the four infants who survived did so because mechanical ventilation was employed and overall cardiopulmonary function was thus improved.

Conclusions

The data presented suggest that mechanical, positive-pressure ventilation can be an effective means of correcting the hypoxia, hypercarbia, and acidosis of infants moribund with respiratory distress syndrome. The effectiveness of IPPV/I in improving oxygenation is determined by the specific pattern of ventilation used. Arterial oxygenation could be improved without significant change in either pHa or $PaCO_2$ by decreasing the respiratory rate and by increasing airway pressure. The clinical improvement of such infants may be related to a change either in pulmonary perfusion or in the ventilation:perfusion ratio. The data indicate that mechanical, positive-pressure ventilation may improve survival rates of infants with severe respiratory distress syndrome.

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33. Requests for reprints should be addressed to: PENELOPE SMITH, M.D., Department of Anesthesia, Stanford University School of Medicine, Stanford, Cal. 94304 (USA).

Appendices

Appendix I. Correlation coefficient of PaO_2, $PaCO_2$, and pHa versus rate (R) for six babies and six study intervals

Study interval h	n	Infant	pO_2 vs R	pCO_2 vs R	pH vs R
0– 12	4	LA	–0.95	–0.35	0.21
	4	LO	–0.80	–	0.14
	7	MT	–0.25	–0.70	–0.22
	6	RO	–0.64	–0.07	0.25
12– 24	6	MT	–0.73	0.31	0.29
	6	FU	–0.86	0.52	0.02
	5	OK	–0.93	0.24	0.06
24– 48	5	MO	–0.10	0.47	–0.91
	6	MT	–0.89	0.66	–0.17
	5	FU	–0.43	0.41	0.17
	6	RO	–0.85	0.09	–0.55
	5	OK	–0.88	–0.67	0.29
	6	OK	–0.88	–0.13	0.18
48– 72	3	LA	–0.95	0.40	–0.94
	5	MO	–0.22	–0.20	0.20
	5	MT	–0.88	0.81	–0.50
	3	FU	0.38	–0.97	0.17
	5	RO	–0.82	0.92	–0.87
	5	OK	–0.78	–0.18	–0.01
72–120	4	LA	0.64	–0.66	0.18
	5	MO	0.38	–0.47	0.52
	6	MT	–0.75	0.16	–0.64
	4	RO	–0.69	0.77	–0.05
	5	OK	–0.55	–0.64	0.78
120–168	4	LA	0.68	–0.83	0.64
	7	MO	–0.66	–0.09	0.63
	4	MO	–0.43	–0.81	0.73

Appendix II. Correlation coefficient of PaO_2, $PaCO_2$, and pHa versus pressure (P) for six babies and six study intervals

Study interval h	n	Infant	pO_2 vs P	pCO_2 vs P	pH vs P
0– 12	4	LA	0.94	0.36	–0.23
	4	MO	0.24	–	–0.37
	7	MT	–0.02	0.86	0.64
	6	RO	0.39	0.01	–0.27
12– 24	6	MT	0.39	–0.31	–0.29
	6	FU	0.85	–0.52	–0.02
	5	OK	0.94	–0.37	0.04
24– 48	5	MO	0.87	–0.18	0.42
	6	MT	0.92	–0.79	0.39
	5	FU	0.43	–0.38	–0.13
	6	RO	0.82	0.21	0.58
	5	OK	0.93	0.38	0.09
	6	OK	0.59	–0.01	0.13
48– 72	3	LA	0.82	–0.13	0.81
	5	MO	0.82	–0.29	0.40
	5	MT	0.88	–0.79	0.49
	3	FU	–0.14	0.99	–0.40
	5	RO	0.87	–0.67	0.70
	5	OK	0.73	–0.18	0.38
72–120	4	LA	–0.16	0.74	–0.95
	5	MO	0.13	–0.20	0.00
	6	MT	0.75	–0.33	0.76
	4	RO	0.53	–0.96	0.37
	5	OK	–0.10	0.15	–0.22
120–168	4	LA	0.10	0.25	–0.06
	7	MO	0.49	0.05	0.03
	4	MO	0.95	0.00	–0.31

Appendix III.

Values for Rate, Pressure, $PaCO_2$, pHa, PaO_2, O_2 saturation, O_2 content and shunt.

Infant	Study	Age at study h	Hours of vent. at study	Type vent.	FiO_2	Rate per min	Pressure cm H_2O	$PaCO_2$ mm Hg	pHa	PaO_2 mm Hg	Hb g %	O_2Sat %	CaO_2 vol. %	$\dot{Q}s/\dot{Q}t$ %
LA	A	64	5	B	1.0	40	52	39	7.51	100	13.1	98.7	17.7	60
						52	48	37	7.51	58		96.1	17.1	81
						68	42	32	7.53	43		91.7	16.2	109
						40	52	31	7.53	88		98.4	17.6	65
	B	128	69	B	1.0	42	53	34	7.46	290	12.2	100.0	17.2	35
						54	41	35	7.41	63		96.3	15.9	79
						50	48	40	7.41	66		96.6	16.0	75
	C	158	99	B	1.0	40	45	30	7.50	153	11.9	99.8	16.4	50
						45	49	23	7.47	126		99.4	16.2	57
						35	56	41	7.40	137		99.5	16.3	53
						50	50	31	7.43	200		100.0	16.6	45
	D	181	122	B	1.0	52	45	26	7.50	92	11.4	98.3	15.3	67
						40	48	27	7.52	99		98.6	15.4	63
						60	46	20	7.59	134		99.5	15.6	56
						50	45	24	7.55	98		98.7	15.4	63
MO	A	21	1	H	1.0	50	37		7.41	40	16.0	85.5	18.4	63
						40	45		7.32	75		96.4	20.8	46
						60	32		7.34	46		87.5	18.8	60
						44	30		7.37	74		96.8	20.9	45
	B	57	37	H	1.0	44	30	52	7.32	48	16.0	88.2	19.0	59
						60	40	63	7.28	54		90.4	19.6	56
						30	43	57	7.37	56		93.5	20.2	52
						50	30	72	7.27	34		68.5	14.8	74
						48	45	60	7.31	72		96.0	20.8	46
	C	91	71	H	1.0	55	35	39	7.39	113	16.2	98.7	21.7	40
						60	35	57	7.33	61		94.2	21.6	41
						70	28	55	7.37	41		84.7	18.5	63
						40	43	62	7.35	61		94.6	20.8	49
						60	43	56	7.38	92		98.0	21.6	42
	D	117	97	H	1.0	60	30	46	7.40	160	15.3	99.5	20.9	
						66	35	49	7.31	81		97.0	20.1	
						60	45	48	7.34	158		99.4	20.9	
						40	45	53	7.27	90		97.4	20.3	
						50	33	71	7.15	41		72.7	15.0	
	E	150	130	H	1.0	69	35	38	7.33	78	13.5	93.4	17.1	50
						70	35	57	7.44	61		95.8	17.6	46
						40	40	59	7.26	108		98.2	18.3	37
						50	35	62	7.21	52		87.0	16.0	58
						50	40	72	7.25	53		90.0	16.5	55
						70	35	82	7.26	41		79.3	14.5	65
						40	45	61	7.25	77		96.0	17.6	45
	F	176	156	H	1.0	48	40	57	7.30	61	12.0	94.3	15.4	48
						50	45	67	7.21	83		96.6	15.9	43
						40	40	92	7.14	71		93.2	15.2	49
						40	48	77	7.17	109		97.7	16.0	41

Appendix III. (Continued)

Infant	Study	Age at study h	Hours of vent. at study	Type vent.	FiO_2	Rate per min	Pressure cm H_2O	$PaCO_2$ mm Hg	pHa	PaO_2 mm Hg	Hb g %	O_2Sat %	CaO_2 vol. %	$\dot{Q}s/\dot{Q}t$ %
MT	A	30	3	B	1.0	50	25	55	7.34	46	12.8	88.0	15.3	62
						50	30	35	7.41	32		77.6	13.5	69
						60	35	40	7.43	24		59.5	10.3	77
						60	25	33	7.39	30		70.5	12.2	73
						40	35	41	7.40	57		94.6	16.4	56
						70	20	–	7.39	39		85.0	14.7	65
						30	40	43	7.40	32		75.0	13.0	71
						42	40	38	7.45	34		80.5	14.0	68
	B	44	17	B	1.0	40	35	52	7.40	42	11.8	86.8	13.8	57
						50	30	51	7.41	46		90.0	14.4	53
						20	45	–	–	220		99.8	16.4	31
						30	40	42	7.45	81		97.7	15.7	41
						60	25	43	7.44	34		79.5	12.6	63
						30	40	41	7.40	51		91.7	14.6	51
	C	54	27	B	1.0	30	40	41	7.37	63	11.4	95.5	14.8	45
						20	45	36	7.38	205		99.7	15.9	32
						20	50	24	7.51	225		99.8	15.9	31
						50	30	39	7.43	37		83.5	12.9	60
						40	35	46	7.41	66		96.4	14.9	44
						25	45	34	7.44	165		99.4	15.7	34
	D	79	52	B	1.0	25	45	40	7.40	172	13.7	99.5	18.8	33
						30	40	34	7.43	91		98.1	18.3	40
						20	50	31	7.45	145		99.2	18.7	35
						40	35	39	7.44	94		98.3	18.3	39
						50	30	44	7.39	48		90.2	16.7	54
	E	102	75	B	1.0	25	45	46	7.39	57	10.3	94.2	13.1	47
						40	35	37	7.39	65		95.9	13.4	44
						20	50	31	7.40	71		96.7	13.6	43
						25	50	27	7.43	68		96.6	13.5	43
						50	30	36	7.36	29		67.0	9.3	68
						25	45	34	7.38	54		93.0	13.0	48
FU	A	57	22	B	1.0	45	35	34	7.57	81	12.3	98.3	16.4	40
						25	45	33	7.54	92		98.5	16.5	39
						35	40	26	7.62	112		99.4	16.4	40
						65	25	36	7.56	46		94.8	15.8	47
						55	30	32	7.58	67		97.7	16.3	41
						35	40	32	7.57	84		98.5	16.5	39
	B	76	41	B	1.0	32	45	33	7.48	36	12.3	83.5	13.9	55
						60	35	33	7.56	56		96.6	16.3	42
						25	50	27	7.58	210		99.8	17.1	31
						42	40	26	7.59	168		99.5	16.9	33
						25	50	–	–	118		–		
	C	84	49	B	1.0	25	45	25	7.67	128	12.3	99.0	16.7	36
						35	40	20	7.74	67		98.8	16.5	39
						45	35	–	–	182		–	–	–
						45	35	19	7.66	230		99.8	17.1	30

Appendix III. (Continued)

Infant	Study	Age at study h	Hours of vent. at study	Type vent.	FiO_2	Rate per min	Pressure cm H_2O	$PaCO_2$ mm Hg	pHa	PaO_2 mm Hg	Hb g %	O_2Sat %	CaO_2 vol. %	$\dot{Q}s/\dot{Q}t$ %
RO	A	19.5	3.5	H	0.75	38	22	37	7.42	42	14.6	87.6	17.3	
						18	32	30	7.44	62		96.0	19.0	
						28	27	23	7.50	68		97.2	19.2	
						48	20	29	7.46	42		89.0	17.5	
						20	38	30	7.43	49		92.2	18.2	
						24	30	44	7.37	70		96.4	19.1	
	B	42	26	H	0.75	20	28	36	7.35	152	13.2	99.3	18.0	
						40	18	34	7.36	71		96.6	17.8	
						30	22	27	7.37	78		97.3	17.4	
						25	30	34	7.42	124		99.1	17.9	
						18	35	29	7.43	122		99.2	17.9	
						20	30	31	7.45	119		99.1	17.9	
	C	67 ½	51 ½	H	0.55	20	27	30	7.44	56	12.8	95.4	15.6	
						42	21	46	7.33	37		80.5	13.1	
						30	35	33	7.43	47		92.2	15.0	
						18	37	32	7.42	59		95.7	15.6	
						18	46	31	7.44	82		98.0	16.1	
	D	90	74	H	0.55	20	34	30	7.41	118	16.5	98.9	22.2	
						32	32	30	7.47	41		89.0	19.8	
						50	26	32	7.45	45		91.1	20.3	
						18	40	26	7.49	81		98.1	21.9	
OK	A	57	16	B	0.94	28	35	39	7.45	210	12.4	99.8	17.1	
						18	40	36	7.52	250		99.9	17.1	
						48	25	41	7.46	45		91.0	15.6	
						38	32	36	7.49	116		98.9	16.9	
						16	40	40	7.42	200		99.7	17.1	
	B	71	30	B	0.80	16	35	28	7.51	156	11.5	99.4	15.8	
						18	40	26	7.58	166		99.5	15.8	
						48	25	25	7.54	50		93.2	14.8	
						38	32	22	7.59	137		99.4	15.8	
						18	38	26	7.53	200		99.7	15.8	
	C	84	43	B	0.50	20	39	24	7.63	104	11.5	99.5	15.8	
						18	35	19	7.68	126		99.7	15.8	
						48	23	23	7.62	60		97.3	15.4	
						38	28	20	7.69	96		99.0	15.7	
						18	30	23	7.64	104		99.1	15.7	
						16	30	24	7.58	135		99.6	15.8	
	D	105	64	B	0.35	16	30	26	7.54	96	11.5	98.7	15.7	
						14	38	24	7.59	84		98.5	15.6	
						38	26	21	7.62	74		98.1	15.6	
						48	20	30	7.49	52		94.2	14.9	
						14	30	36	7.48	73		95.7	15.2	
	E	128	87	B	0.35	14	29	15	7.62	114	14.8	99.4	20.3	
						48	21	14	7.71	74		98.7	20.2	
						14	35	16	7.60	115		99.4	20.3	
						38	24	13	7.70	100		99.4	20.3	
						20	22	18	7.52	198		99.9	20.4	