Effects of Anaesthesia with a High Oxygen Concentration on the Acid-Base State of Babies Delivered at Elective Caesarean Section

A. ROBERTSON, R. J. FOTHERGILL, R. A. HALL, R. A. BOND

SUMMARY

Babies delivered from mothers who had 60% oxygen administered during general anaesthesia at elective Caesarean section, had higher pH and lower pCO_2 levels, and were clinically in better condition than babies delivered after a similar induction-delivery interval when a concentration of 30 - 33% oxygen was given to the mother. The clinical and acid-base states in both these groups of babies were not as good as in those delivered after induction-delivery times of less than 6 minutes.

S. Afr. Med. J., **48**, 2309 (1974).

The ideal technique for general anaesthesia for Caesarean section is by no means settled. Controversies continue about the best choice of method. In a previous publication,[1] we showed that when a standard anaesthetic technique was used, the condition of babies delivered by elective Caesarean section within 6 minutes of induction of anaesthesia ('fast' group) was better than that of those delivered after a prolonged induction-delivery interval ('slow' group). This standard technique consisted of a sequence of thiopentone, succinylcholine and nitrous oxide, with a 30 - 33% concentration of oxygen. The standard technique of anaesthesia is described in our previous article.[5]

After this first study we embarked upon a comparison of anaesthetic techniques, trying to find a method which would give results that, despite a prolonged interval between induction and delivery, were as good as those we had found with a very short induction-delivery interval, using the standard technique.

The previous work had shown that the partial pressure of oxygen (pO_2) in maternal capillary blood at the time of delivery was lower in the 'slow' group than in the 'fast' group. We had suspected that the neonatal acidaemia found in the 'slow' group might have been caused by insufficient maternal oxygenation arising because of the long time lapse after induction of anaesthesia. In the present study we have compared 'fast' and 'slow' groups given the standard anaesthetic technique with a third group, the 'trial' group, in which the mothers were given a 60% concentration of oxygen.

Good Hope Maternity Hospital, Sutton Coldfield, Warwickshire, UK

A. ROBERTSON, *Sheldon Research Fellow* (Present address: 224 Rhodes Ave, Salisbury, Rhodesia)
R. J. FOTHERGILL, *Consultant Gynaecologist*
R. A. HALL, *Biochemist*
R. A. BOND, *Consultant Anaesthetist*

Date received: 23 July 1974.
Reprint requests to: Dr A. Robertson, 224 Rhodes Ave, Salisbury, Rhodesia.

PATIENTS AND METHODS

Twenty-six patients undergoing elective Caesarean section were divided into 3 groups and studied as follows:

1. The 'fast' group, in which delivery took place within 6 minutes of induction of anaesthesia (9 babies).

2. The 'slow' group, in which delivery took place between 16 and 42 minutes from induction of anaesthesia (9 babies). The 'fast' and 'slow' groups in this study were fully comparable with the 'fast' and 'slow' groups described in the previous article, and the method of anaesthesia was the same.

3. A 'trial' group, in which delivery took place between 22 and 35 minutes from induction, but the mothers were given 60% oxygen during anaesthesia (9 babies).

The method of anaesthesia for the 'trial' group differed from that in the 'slow' group by the omission of nitrous oxide, and the use of halothane in an oxygen-air mixture. In both these groups anaesthesia was induced in the anaesthetic room, then the patient was catheterised, taken on a trolley into the theatre, placed on the operating table and swabbed and draped before the operation was commenced. Oxygen (100%) was administered for 3 - 5 minutes before anaesthesia was induced with sodium thiopentone, and endotracheal intubation was accomplished with the aid of 100 mg succinylcholine. In the 'trial' group anaesthesia was maintained with halothane 0,5 to 1,5% (except for case 13 in whom a concentration of 2% was given) in an oxygen-air mixture of equal proportions, thereby providing approximately 60% oxygen.

The indications for Caesarean section and the ages and parity of the patients were fully comparable in the 3 groups. Ten of the 26 patients fell into the class defined by Crawford[2] as Group A (cases 4, 8, 12, 13, 16, 22, 23, 24, 25 and 26) and of these, 4 were in the 'slow' group, and 3 each in the other 2 groups. All but 4 of the babies weighed more than 3 kg and all the birthweights were above 2,81 kg. One case of twins was included (case number 17) and, for statistical reasons, the mean of the readings for the 2 babies has been taken and included

in the tables. The surgical technique was virtually identical in all cases.

Capillary blood was taken from the hyperaemic maternal finger-tip at the time of delivery of the baby. Umbilical cord venous and arterial samples were taken from a loop of cord which had been clamped immediately at delivery. These samples were obtained and examined in the manner described in our previous article, and the same Radiometer Blood Micro System (BMS 3) was used. The partial pressure of oxygen was measured with a direct reading pO_2 electrode, and the oxygen saturation was calculated for maternal and umbilical cord blood from nomograms described by Astrup *et al.*[3] and Hellegers[4] respectively. All readings were done in duplicate or triplicate. The standard bicarbonate and base excess were calculated from the blood gas calculator designed by Severinghaus,[5] with an assumed haemoglobin level of 15,0 g/100 ml. (The mean maternal haemoglobin at delivery was in fact 12,8 g/100 ml).

The resident paediatric medical officer examined each baby at delivery and made a completely independent assessment of the Apgar scores at 1 and 5 minutes after delivery. The 2 points usually allocated for the colour of the baby have been omitted, and the scores stated in this article are out of a total of 8 points ('Apgar minus colour').

RESULTS

The measurements obtained from the maternal capillary blood and the cord arterial and venous blood are detailed in Tables I, II and III, and summarised in Table IV. The 3 groups were compared with respect to each factor using analyses of variance.

pH

In the 'fast' group the lowest cord arterial blood pH was 7,29 and the mean for the group was 7,33. The mean cord venous blood pH in this group was also 7,33. These are better results than in the 'slow' group, in which the mean figures were 7,22 and 7,25 for the cord arterial and venous blood respectively. This difference is statistically significant ($P<0,01$ and $P<0,01$).

In the 'trial' group the mean cord arterial and cord venous pH values were 7,25 and 7,27. These are lower than, and significantly different from, the means of the 'fast' group ($P<0,05$ and $P<0,05$), but the differences are not as marked as those between the 'fast' and 'slow' groups. The differences between the means for the cord arterial and venous pH results in the 'slow' and 'trial' groups are not significant.

pCO_2

The differences between the means for the cord arterial and cord venous pCO_2 results in the 'fast' and 'slow' groups are also significant ($P<0,001$ and $P<0,001$). The cord arterial pCO_2 ranged from 28 to 51 mmHg in the

TABLE I. 'FAST' GROUP

Case No.	Maternal capillary blood at delivery					Umbilical cord arterial blood					Umbilical cord venous blood					Apgar score minus colour		Induction-delivery time (min)
	pH	pCO_2	Base excess	Std HCO_3	pO_2	Oxygen saturation	pH	pCO_2	Base excess	Std HCO_3	pO_2	Oxygen saturation	pH	pCO_2	Base excess	Std HCO_3	pO_2	Oxygen saturation	1 min	5 min	
1	7,40	28	— 6,0	20,0	97	97,4	7,30	41	—6,0	19,5	26	58	7,27	50	—5,0	20,5	25	53	8	8	5
6	7,45	28	— 3,2	22,0	102	97,8	7,33	51	—0,2	24,5	17	34	7,32	46	—3,0	22,2	37	79	8	8	3
7	7,48	13	—11,5	16,0	170	98,8>	7,33	36	—6,5	19,5	20	44	7,34	33	—7,2	18,8	27	64	8	8	4
8	7,46	22	— 6,2	19,5	97	97,7	7,38	28	—7,2	18,8	35	80	7,30	42	—5,7	19,7	21	45	8	8	5
9	7,42	27	— 5,5	20,2	160	98,8>	7,33	36	—6,5	19,5	29	67	7,25	50	—6,2	19,7	24	49	8	8	6
19	7,45	25	— 4,8	20,7	62	93,0	7,29	45	—5,5	20,2	30	80>	7,32	39	—5,7	19,8	47	80>	8	8	4
21	7,41	20	—10,2	17,2	53	88,0	7,31	38	—6,8	19,2	8	<20	7,35	31	—7,5	18,8	19	42	3	5	3
22	7,48	19	— 7,2	18,8	59	93,0	7,37	31	—6,3	19,5	15	30	7,41	24	—7,8	18,5	40	80>	6	5	6
23	7,62	15	— 3,0	22,2	105	98,6	7,35	36	—5,2	20,3	17	36	7,42	31	—3,4	21,8	27	70	4	8	5

Data from 9 elective Caesarean sections in which delivery took place in less than 6 minutes after induction of anaesthesia.

TABLE II. 'SLOW' GROUP

Case No.	Maternal capillary blood at delivery						Umbilical cord arterial blood						Umbilical cord venous blood						Induction-delivery time (min)	Apgar score minus colour	
	pH	pCO_2	Base excess	Std HCO_3	pO_2	Oxygen saturation	pH	pCO_2	Base excess	Std HCO_3	pO_2	Oxygen saturation	pH	pCO_2	Base excess	Std HCO_3	pO_2	Oxygen saturation		1 min	5 min
2	7,33	35	−6,8	19,2	73	93,5	7,27	56	− 2,7	22,3	44	80>	7,20	60	− 6,3	19,5	9	<20	25	3	5
3	7,43	25	−6,0	19,7	91	97,1	7,21	38	−13,0	15,2	25	48	7,24	47	− 8,0	18,4	27	55	20	8	8
4	7,44	22	−8,5	18,2	20	35,0	7,16	47	−13,0	15,0	3	<20	7,16	52	−11,7	15,8	19	27	20	7	8
5	7,28	37	−9,3	17,6	56	84,0	7,21	74	− 1,3	23,5	9	<20	7,23	70	− 1,2	23,7	24	47	23	4	8
18	7,39	29	−6,2	19,6	70	94,0	7,12	63	−10,2	16,3	13	<20	7,22	46	−10,0	17,2	36	71	34	3	5
20	7,42	27	−5,5	20,2	78	95,8	7,15	52	−12,3	15,6	23	38	7,21	50	− 9,0	17,8	34	67	42	5	6
24	7,59	17	−2,9	22,2	85	97,7	7,31	43	− 4,8	20,7	12	<20	7,36	34	− 5,6	20,0	18	40	20	2	7
25	7,48	24	−3,8	21,5	67	95,0	7,26	49	− 5,8	19,7	6	<20	7,29	47	− 4,7	20,7	11	<20	20	4	6
26	7,35	32	−7,2	19,0	65	91,5	7,29	48	− 4,2	21,2	11	<20	7,30	47	− 3,8	21,4	21	44	16	4	5

Data from 9 elective Caesarean sections in which delivery took place between 16 and 42 minutes after induction of anaesthesia.

TABLE III. 'TRIAL' GROUP

Case No.	Maternal capillary blood at delivery						Umbilical cord venous blood						Umbilical cord arterial blood						Induction-delivery time (min)	Apgar score minus colour	
	pH	pCO_2	Base excess	Std HCO_3	pO_2	Oxygen saturation	pH	pCO_2	Base excess	Std HCO_3	pO_2	Oxygen saturation	pH	pCO_2	Base excess	Std HCO_3	pO_2	Oxygen saturation		1 min	5 min
10	7,42	25	− 6,5	19,3	84	96,5	7,24	46	− 8,3	18,2	26	53	7,21	51	− 8,7	18,0	18	28	26	1	4
11	7,46	14	−11,7	15,8	137	98,8	7,34	27	−10,3	17,0	32	73	7,24	38	−11,4	16,3	14	<20	35	6	8
12	7,55	13	− 8,5	18,2	105	98,4	7,41	25	− 7,2	18,9	22	57	7,38	26	− 8,3	18,2	24	60	31	3	5
13	7,34	32	− 7,8	18,7	75	94,2	7,16	54	−11,2	16,3	14	<20	7,28	43	− 6,8	19,2	33	70	28	2	6
14	7,44	24	− 6,0	19,7	131	98,6	7,27	50	− 4,8	20,5	25	53	7,29	46	− 5,0	20,5	31	68	22	8	8
15	7,45	22	− 6,8	19,2	148	98,8	7,18						7,28	34	−10,5	16,8	45	80>	22	8	8
16	7,39	25	− 8,3	18,3	160	98,8>	7,16	46	−13,3	14,8	16	<20	7,21	36	−13,7	14,7	27	58	29	5	7
17	7,30	40	− 6,5	19,3	92	96,1>	7,22	47	− 8,9	17,8	29	58	7,24	47	− 7,8	18,5	36	72	28	8	8

Data from 8 elective Caesarean sections in which the mother was given 60% oxygen. Case 17 had twins.

TABLE IV. MEANS OF INDIVIDUAL RESULTS

		pH (units)	pCO_2 (mmHg)	Base excess (mEq/l)	Std HCO_3 (mEq/l)	pO_2 (mmHg)	Oxygen saturation (%)
'Fast' group	Maternal capillary blood	7,46	21,9	−6,4	19,6	100,6	95,9
		(0,07)	(5,6)	(2,9)	(2,1)	(41,7)	(3,8)
	Umbilical cord arterial blood	7,33	38,0	−5,6	20,1	21,8	49,9
		(0,03)	(7,0)	(2,1)	(1,7)	(8,6)	(22,2)
	Umbilical cord venous blood	7,33	38,4	−5,7	20,0	29,7	62,4
		(0,06)	(5,8)	(1,7)	(1,3)	(9,5)	(15,6)
'Slow' group	Maternal capillary blood	7,41	27,6	−6,2	19,7	67,2	87,1
		(0,09)	(6,6)	(2,0)	(1,5)	(20,6)	(19,9)
	Umbilical cord arterial blood	7,22	52,2	−7,5	18,8	16,2	31,8
		(0,07)	(10,9)	(4,7)	(3,3)	(13,1)	(20,8)
	Umbilical cord venous blood	7,25	50,3	−6,7	19,4	22,1	43,4
		(0,06)	(10,0)	(3,3)	(2,4)	(9,3)	(18,8)
'Trial' group	Maternal capillary blood	7,41	26,1	−7,6	18,6	113,8	97,4
		(0,08)	(8,8)	(1,8)	(1,2)	(34,8)	(1,7)
	Umbilical cord arterial blood	7,25	42,1	−9,1	17,6	23,4	47,7
		(0,09)	(11,8)	(2,8)	(1,8)	(6,6)	(20,1)
	Umbilical cord venous blood	7,27	40,1	−9,0	17,8	28,5	57,0
		(0,06)	(8,2)	(2,8)	(2,2)	(10,0)	(21,6)

The means of the individual results listed in Tables I, II and III. The standard deviations are shown in brackets underneath.

'fast' group, with a mean of 38,0 mmHg. The mean cord venous pCO_2 in the 'fast' group was 38,4 mmHg. In the 'slow' group the pCO_2 levels were higher and the means were 52,2 (arterial) and 50,3 (venous) mmHg. The results in the 'trial' group were intermediate between the 'fast' and 'slow' groups, the mean cord arterial pCO_2 being 42,1 mmHg and the mean cord venous pCO_2 being 40,1 mmHg. The cord arterial and venous pCO_2 values of the 'trial' group are not significantly different from those of the 'fast' group, but they are less than those of the 'slow' group ($P<0,05$ for the cord arterial blood and $P<0,01$ for the cord venous blood).

Base Excess and Standard Bicarbonate

The mean base excess and standard bicarbonate levels of the cord arterial and venous samples demonstrated more acidosis in the 'slow' group than in the 'fast' group, but those in the 'trial' group were even more acidotic than those in the 'slow' group. These differences were not statistically significant.

Maternal Capillary Blood pH

The mean maternal capillary blood pH at the time of delivery in the 'fast' group was 7,46 units. In case 23 the pH was abnormally high, and if this result were excluded, the mean for the remaining 8 cases was 7,44. These results were higher than those in the 'slow' and 'trial' groups, in both of which the mean maternal pH was 7,41. The difference between the mean of 7,46 of the 'fast' group and that of the 'slow' and 'trial' groups is, however, not statistically significant.

Other Measurements

Similarly, **the mean maternal capillary blood pCO_2** was lower in the 'fast' group than in both the 'slow' and 'trial' groups, but the difference between the mean of the 'fast' group and that of the 'slow' and 'trial' groups is again not statistically significant.

The mean maternal capillary blood pO_2 at the time of delivery and the **mean cord arterial pO_2** levels were highest in the 'trial' group. There is a significant difference between the mean maternal pO_2 of the 'trial' group and that of the 'slow' group ($P<0,01$), and also between that of the 'fast' group and that of the 'slow' group ($P<0,05$). Despite the higher maternal pO_2 levels in the 'fast' and 'trial' groups, the differences between the mean cord arterial and cord venous pO_2 levels in the 3 groups are not significant.

The cord arterial and venous oxygen saturations were lowest in the 'slow' group, and highest in the 'fast' group, but the differences between the means of both the cord arterial and venous blood in the 3 groups are again not statistically significant.

The induction-delivery times correlate significantly with the cord arterial and venous blood pH, with the base excess and standard bicarbonate ($r = -0,57$; $-0,51$ and $-0,50$ and $r = -0,56$; $-0,50$ and $-0,47$ respectively), but do not correlate significantly with the cord arterial and venous pCO_2 nor with the cord pO_2 and oxygen saturation levels. None of the maternal capillary blood results correlate with the induction-delivery times.

The 'Apgar minus colour' scores were more favourable in the 'fast' group of cases than in the other two groups, and were least favourable in the 'slow' group. Six babies in the 'fast' group had 'Apgar minus colour' scores of

8 out of 8 at 1 minute, and 7 had scores of 8 at 5 minutes. In the 'slow' group there was only one baby with a score of 8 at 1 minute, and even at 5 minutes only 3 scored 8. In the 'trial' group 4 babies, including the twins, had scores of 8 at 1 minute, and at 5 minutes 5 had this score. All the babies in the series were alive and well at late review.

Bleeding: No cases in the 'fast' or 'slow' groups bled excessively during the operations, and none of them required a blood transfusion. In the 'trial' group 4 of the 8 patients needed a blood transfusion. A total of 11 units of blood was given, and 2 cases needed 4 units each. The excessive bleeding in the 'trial' group must have been the result of the relaxant effect of halothane on the uterus.

DISCUSSION

In our previous article[1] we demonstrated neonatal acidaemia in cases in which the induction-delivery interval was prolonged. We suspected that this might have been due to insufficient maternal oxygenation. The present series was designed to raise the maternal pO_2 at the time of delivery in the 'trial' group, and to bring to light any consequent effects on the acid-base state of the babies. The mean maternal capillary blood pO_2 was in fact raised significantly ($P<0,01$) in the 'trial' group by the administration of approximately 60% oxygen. The cord arterial and venous pCO_2 values were lower in the 'trial' group than in the 'slow' group ($P<0,05$ and $P<0,01$), but the pH values were not significantly different in the 2 groups. The Apgar scores were better in the 'trial' group than in the 'slow' group, but unfortunately the improvement was only slight. The babies in the 'trial' group did not achieve the good acid-base state, nor the good Apgar scores of those in the 'fast' group. In a further series (in preparation) the maternal pO_2 has been raised by the technique of 'nitrous oxide washout', but this has again failed to bring about a marked improvement in the acid-base state and in the oxygenation of the babies.

The mean maternal pO_2 in our 'trial' group was significantly higher than that of the 'slow' group, but did not reach the maternal arterial pO_2 levels achieved by Rorke *et al.*[6] in their 65,4% oxygen group. This difference was partly the result of our use of capillary blood samples. The results of Rorke *et al.*[6] in regard to other values, were comparable to our own. The mean cord arterial pH results in their 'low' and 'high' oxygen concentration groups were 7,233 and 7,235 respectively. These figures may be compared with 7,22 and 7,25 in our 'slow' and 'trial' groups. The mean maternal pH values in our 'slow' and 'trial' groups were also very similar to those in their 'low' and 'high' oxygen concentration groups (7,433 and 7,414). The total gas volume which they used was 12 litres/minute, whereas we gave less than 10 litres/minute. Consequently, we are now studying the effects of higher total gas volumes on the acid-base state of the newborn.

Our findings confirm those of Rorke *et al.*[6] and Baraka,[7] and show that an increase in oxygen concentration of up to 50 or 60% administered to mothers at Caesarean section produces some increase in neonatal oxygenation. In our 'slow' and 'trial' groups taken together, the linear correlation coefficient (r value) for the maternal pO_2 and the cord arterial pO_2 was + 0,43; the r value for the maternal pO_2 and cord venous pO_2 was + 0,31. Rorke *et al.*[6] also showed a significant correlation in their 'low' and 'high' groups between the individual values of maternal arterial blood pO_2 and cord venous pO_2.

CONCLUSION

We are disappointed that increased maternal oxygenation has not offset the disadvantages of a prolonged induction-delivery interval. In another study[8] we have found that the use of propanidid (Epontol) in 'slow' cases has given some improvement in the results, but again these results are not as good as those in the fast cases. It seems that the best anaesthetic for Caesarean section is the shortest.

We wish to thank Mr W. S. Crawford and Mr C. W. Mortimer for allowing us to include patients under their care in the investigations; Drs W. Castle and M. Wall for statistical help; and the Birmingham Regional Hospital Board for financial assistance provided through the award of a Sheldon Clinical Research Fellowship to A. R.

REFERENCES

1. Fothergill, R. J., Robertson, A. and Bond, R. A. (1971): J. Obstet. Gynaec. Brit. Cwlth, **78**, 1010.
2. Crawford, J. S. (1965): *Principles and Practice of Obstetric Anaesthesia*, 2nd ed. Oxford: Blackwell.
3. Astrup, P., Engel, K., Severinghaus, J. W. and Munson, E. (1965): Scand. J. Clin. Lab. Invest., **17**, 515.
4. Hellegers, A. E. *in* Carey, H. M. ed. (1963): *Modern Trends in Human Reproductive Physiology*, p. 307. London: Butterworths.
5. Severinghaus, J. W. (1966): J. Appl. Physiol., **21**, 1108.
6. Rorke, M. J., Davey, D. A. and Du Toit, H. J. (1968): Anaesthesia, **23**, 585.
7. Baraka, A. (1970): Brit. J. Anaesth., **42**, 434.
8. Robertson, A., Fothergill, R. J. and Bond, R. A. (1974): S. Afr. Med. J., **48**, 1019.