THE USE OF THE BAIN CIRCUIT IN SPONTANEOUSLY BREATHING PAEDIATRIC PATIENTS

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THE BAIN CIRCUIT or the modified Mapelson D&E systems have several advantages over other anaesthetic circuits in clinical use.[1]

Studies of the performance of the Bain circuit when used in adults with controlled ventilation showed that arterial carbon dioxide tension remained within normal limits when the total fresh gas flow was as low as 70 ml/kg/min and not less than 3.5 l/min.[2]

In the present study we have examined the changes in the arterial carbon dioxide tension when the Bain circuit is used in paediatric patients breathing spontaneously under general anaesthesia, with fresh gas flow equal to the calculated minute volume.

METHOD

Thirty-five patients one to five years of age and weighing 6.7 kg to 20 kg were the subjects of this study. After explaining the procedure and obtaining informed consent from the parents, the children underwent eye surgery under general anaesthesia with spontaneous respiration through the Bain circuit (Table I).

Thirty-two patients were ASA physical status I and the other three were status II. All patients had clinically normal cariovascular and respiratory systems.

Patients received nothing *per os* for at least six hours before operation. Preanaesthetic medication consisted of meperidine 1 mg/kg, hydroxyzine hydrochloride (Atarax) 1 mg/kg, and atropine or scopolamine 0.01 mg/kg intramuscularly, one hour before induction.

Anaesthesia was induced and maintained with oxygen, nitrous oxide, and halothane. The inspired concentration of halothane was adjusted to obtain clinically adequate anaesthesia. Tracheal intubation was done without the use of relaxants, and without assisted ventilation.

The minute volume was calculated as follows: 1. Body surface area was calculated; 2. The minute alveolar ventilation at B.T.P.S. was predicted from the Engström ventilation tables[3]; 3. The minute volume was derived by considering the VD/VT ratio to be equal to 0.33.[4]

For each patient the oxygen and the nitrous oxide flowmeters were set to deliver a total fresh gas flow equal to the calculated minute volume with an inspired oxygen concentration of 30 per cent to 50 per cent.

Arterial blood samples were drawn immediately after induction in 24 patients and again during operation after 45 minutes of spontaneous breathing in all patients and analysed immediately for Po_2, Pco_2 and pH.

During the procedure we recorded the heart rate, arterial blood pressure and inspiratory rate. The presence of cardiac arrythmias, sweating and change in body temperature were also observed. These parameters were monitored as guides to the depth of anaesthesia and as clinical signs of hypercapnia.

RESULTS

Table II shows the total fresh gas flow used with the Bain circuit in our study. The mean fresh gas flow was 206 ml/kg/min or 4.77 l/m^2/min.

The mean values and the standard errors of the mean of the arterial blood gases after induction and after 45 minutes of spontaneous breathing are shown in Table III. Arterial oxygenation was normal or above normal in all patients. Clinical signs of hypercapnia were absent in all cases. This was confirmed by the blood gas analyses which showed the Pa_{CO_2} had not exceeded the normal limits in any patient. On the other hand, hypocapnia with Pa_{CO_2} as low as 3.39 kPa (25.5 torr) was observed in some of the patients.

Study of the acid base status showed acidosis of metabolic origin in a considerable number of our patients (Table IV).

The arterial Pco_2 immediately after induction

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TABLE I

N	Age (years)	Sex F	Sex M	Classification A.S.A. I	Classification A.S.A. II	Weight (kg)	Body surface area m²	Procedure
35	1–5	13	22	32	3	6.7–20	0.36–0.81	Strabismus

TABLE II

Total Fresh Gas Flow Used

ml/kg/min		l/m²/min	
Mean	±S.E.	Mean	±S.E.
206	3.5	4.77	0.065

and 45 minutes later in 24 patients are compared in Table V. There was no significant difference.

Discussion

From our observation, when the Bain circuit is used in spontaneously breathing patients with a body weight less than 20 kg a fresh gas flow equal to the calculated minute volume with a mean of 206 ml/kg/min or 4.77 l/m²/min should be sufficient to maintain the arterial Pco_2 within or below the normal limits.

All our patients weighed between 6.7 and 20 kg and breathed spontaneously. The fresh gas flows used ranged from 171 to 255 ml/Kg/min.

These fresh gas flows values are comparable to those recommended by Bain and Spoerel.[5] In their study on carbon dioxide output and elimination they found that fresh gas flow over 200 ml/kg/min is required when the Bain circuit is used in children under 10 kg body weight. They also found that the fresh gas flow required is gradually decreased to around 100 ml/kg/min for patients above 30 kg body weight. These required flows were suggested regardless of the mode of breathing.

A report by Conway[6] showed that rebreathing occurs when the Bain circuit is used with low fresh gas flows. Although the method we used for this study cannot confirm or eliminate the presence of rebreathing, our results show that if such low flows are associated with rebreathing, normal children under anaesthesia can compensate for it by increasing their minute ventilation and thus maintain normal Pa_{CO_2}.

The fact that we calculated the minute volume instead of measuring it may raise doubt that the total fresh gas flow used may be higher than the actual minute volume. Doershuck *et al.*,[7] measured the minute volume by body plethysmograph in sedated, supine children one month to five years of age. They found that the average minute volume in this age group is 234 ± 77 ml/kg/min. When we compare these measured values with our calculated values, there is no significant difference. Since the two groups of patients are comparable, we can assume that the calculated minute volume in our study was equal to or less than the reality.

The hypocapnia observed in some of our patients is probably a respiratory compensation for the metabolic acidosis caused by fasting. The Pa_{CO_2} after 45 minutes of spontaneous breathing plotted against the base excess shows a correlation with a coefficient of 0.72 (Figure 1). These changes in the acid-base status were present immediately after induction in 24 of our patients and showed no significant change after 45 minutes of anaesthesia.

The low fresh gas flow required to maintain Pa_{CO_2} within the normal values is an advantage of the Bain circuit, since this leads to less pollution in the operating theatre, less effect of dry gases delivered to the patient and economy of gases.

The versatility of the circuit from spontaneous breathing to mechanical ventilation with no change in the fresh gas flow, makes it easier to use: however, consequent change in the minute ventilation will be required to maintain the arterial Pco_2 within the normal limits.[8]

Care should always be taken to verify the integrity of the circuit before its use. Cases of severe hypercapnia have been reported[9,10] due to improper connection of the circuit. The degree of hypercapnia will be greater if the defective circuit is used with spontaneous breathing.

Summary

We studied the use of Bain circuit in children under general anaesthesia, intubated without the

TABLE III

Arterial Blood Gases
mean ± SE

Sampling time	P_{O_2}		P_{CO_2}		H^+ nmol/l	pH	B.E. mmol/l
	kPa	Torr	kPa	Torr			
After induction	19.42 ± 0.6	146 ± 4.5	4.79 ± 0.08	36 ± 0.6	44 ± 1	7.36 ± 0.01	−3.8 ± 0.6
45 min after	19.55 ± 0.6	147 ± 4.3	4.79 ± 0.12	37 ± 0.9	45 ± 1	7.35 ± 0.01	−4.8 ± 0.5

TABLE IV

	Age (years)	Sex	Weight (kg)	Height (cm)	Flow (l/min)	Oxygen (%)	P_{O_2} kPa	P_{O_2} Torr	P_{CO_2} kPa	P_{CO_2} Torr	H^+ nmol/l	pH	B.E. mmol/l
1	3	M	17	107	3	33	16.63	125	5.52	41.5	45	7.35	−2.8
2	3	M	12	95	2.75	35	22.61	170	4.97	37.4	48	7.32	−6.1
3	3	M	12.3	105	2.55	30	13.10	98.5	5.00	37.6	49	7.31	−6
4	5	F	17.5	111	3	33	16.63	125	5.11	38.4	54.6	7.26	−9.1
5	5	M	17	108	3	33	22.21	167	4.44	33.4	43	7.37	−5.3
6	4	M	17	108	3	33	21.28	160	4.48	33.7	50	7.3	−9.2
7	3	M	15.5	105	2.9	30	16.49	124	4.16	31.3	44	7.36	−6.8
8	1	F	11	77	2.5	30	15.69	118	4.46	33.5	47	7.33	−7.5
9	1.5	M	10	79	2.2	30	16.89	127	4.26	32	50	7.3	−9.7
10	1	M	11	84	2.5	30	18.09	136	3.72	28	48	7.32	−10.6
11	2.5	M	11	86	2.5	33	22.61	170	4.79	36	39	7.41	−1.2
12	4	F	14.2	97	2.8	40	20.08	151	4.97	37.4	43	7.37	−2.5
13	3	F	12.5	101	2.7	40	24.37	183	5.39	40.5	44	7.36	−2.5
14	3.5	M	15	89	3	30	19.55	147	5.39	40.5	41	7.39	−0.8
15	3	M	15	110	3	30	19.55	147	4.66	35	45	7.35	−5.8
16	5	M	19.5	112	3.6	35	18.35	138	5.19	39	43	7.37	−1.9
17	5	M	20	110	3.6	30	19.95	150	5.19	39	44	7.36	−3
18	4	F	16	106	3	30	15.16	114	5.79	43.5	49	7.31	−3
19	2	M	11	85	2.5	30	20.08	151	3.39	25.5	44	7.36	−9.6
20	2.5	F	13	90	2.75	30	23.28	175	5.05	38	42	7.38	−1
21	1	M	6.7	73	1.7	30	20.22	152	4.52	34	44	7.36	−5
22	4.5	F	14.5	104	3	33	19.15	144	4.39	33	46	7.34	−7
23	1.5	M	11.3	80	2.5	35	16.89	127	5.65	42.5	47	7.33	−3
24	2	M	13	85	2.8	40	16.09	121	5.59	42	48	7.32	−4
25	2.5	F	12	89	2.6	50	26.73	201	4.92	37	41	7.39	−1.5
26	1	F	8.6	71	2	50	28.46	214	3.59	27	40	7.40	−6.5
27	4	F	17	108	3.1	35	19.95	150	5.72	43	49	7.31	−4.4
28	3	M	17	102	3.1	35	16.63	125	5.25	39.5	47	7.33	−4.5
29	5	M	19	113	3.5	50	17.02	128	4.59	34.5	48	7.32	−7.2
30	3	M	14.5	96	3	33	17.96	135	5.99	45	46	7.34	−1.8
31	1.5	F	10.8	84	2.6	40	22.88	172	4.59	34.5	42	7.38	−3.9
32	1.5	M	10.5	79	2.4	40	16.49	124	4.12	31	48	7.32	−9
33	5	F	18	108	3.2	30	19.42	146	5.72	43	43	7.37	−0.7
34	3	M	13.5	95	2.9	40	21.41	161	5.19	39	39	7.41	−0.5
35	5	F	18	119	3.2	40	21.95	165	3.59	27	41	7.39	−7.3

TABLE V

ARTERIAL PCO_2 IN 24 PATIENTS

After Induction		45 min later	
kPa	Torr	kPa	Torr
5.05	38	5.49	41.3
4.79	36	4.97	37.4
4.39	33	5.00	37.6
4.85	36.5	5.11	38.4
4.52	34	4.44	33.4
3.99	30	4.16	31.3
5.05	38	4.79	36
4.66	35	4.97	37.4
5.05	38	5.37	40.4
4.97	37.4	5.37	40.4
4.81	36.2	4.63	34.8
5.05	38	5.20	39.1
4.97	37.4	5.15	38.7
5.19	39	5.79	43.5
3.59	27	3.39	25.5
4.99	37.5	5.05	38
4.79	36	4.55	34.2
4.66	35	4.39	33
5.05	38	5.65	42.5
5.25	39.5	5.71	42.9
5.12	38.5	5.25	39.5
4.79	36	4.59	34.5
5.19	39	5.97	44.9
5.45	41	5.72	43

use of muscle relaxants and breathing spontaneously. The fresh gas flow was equal to the calculated minute volume with a mean of 206 ml/kg/min.

No clinical signs of hypercapnia were observed. Arterial blood gas analyses showed that Pa_{CO_2} was normal or below normal. There was no significant difference between arterial PCO_2 immediately after induction and after 45 minutes of spontaneous breathing.

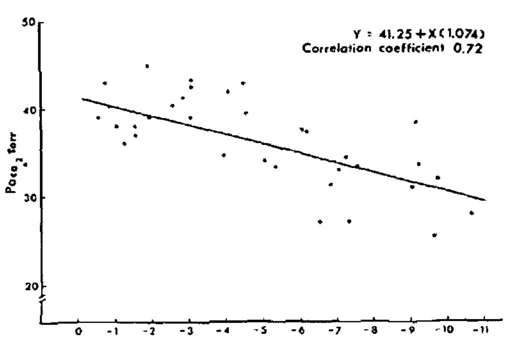

FIGURE 1 The relation between arterial carbon dioxide tension (Pa_{CO_2}) and base excess.

We explain the hypocapnia observed in some patients as a compensatory respiratory alkalosis, in response to the metabolic acidosis caused by fasting.

Thus we can assume that the Bain system is safe for use in normal children during general anaesthesia with spontaneous breathing.

RÉSUMÉ

Nous avons utilisé le circuit Bain chez des patients pédiatriques (6.7–20 g) subissant une cure de strabisme, et nous avons étudié les changements de PCO_2 arteriel.

Les patients étaient à jeûn depuis au moins six heures, et recevaient leur prémédication une heure avant l'induction qui se faisait, au masque, avec l'aide d'O_2 dans des proportions de 30–50 pour cent, protoxyde d'azote et halothane. Lorsque la condition clinique le permettait, on procédait à l'intubation oro-trachéale, sans l'aide de myorésolutif.

En aucun moment la ventilation ne fut assistée ou contrôlée: advenant obstruction respiratoire haute, le patient était rayé de l'étude.

Le maintien de l'anesthésie se faisait avec un flot de gaz frais, égal au volume minute, calculé (moyenne 206 ml/kg/min, ou 4.77 $l/m^2/min$).

Nous avons étudié 35 patients: 32 ASA status I; 3 ASA status II.

Aucun signe clinique ou physiologique d'hypercapnée ne fut noté.

L'analyse des gaz sanguins par ponction radiale ou pédieuse montre une normo ou hypocapnie chez tous nos patients: nous n'avons pas noté de différence significative entre la Pa_{CO_2} immédiatement après l'induction et 45 minutes plus tard en respiration spontanée.

L'hypocapnie notée chez quelques patients est fort probablement secondaire à une alcalose respiratoire compensatrice pour l'acidose métabolique causée par le jeûne prolongé.

L'expérience fut concluante et indique à notre avis que le circuit Bain employé chez l'enfant en respiration spontanée, avec un débit de gaz frais minimal de 206 ml/kg/min, en moyenne, élimine la rétention de CO_2 si le patient n'a pas de limites à sa capacité de ventilation, en plus de fournir les autres avantages connus.

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