ARTERIAL-BLOOD GAS STUDIES ASSOCIATED WITH ANAESTHESIA FOR ADENOTONSILLECTOMY IN CHILDREN*

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THE TECHNIQUES employed for this, "the most neglected of anaesthetic procedures,"¹ are often no credit to our specialty

The present Department of Anaesthesia at the Children's Hospital, Winnipeg, was fortunate to inherit a surgical clientele already conditioned to nasal endotracheal intubation for this procedure. With one or two exceptions, the transition to oral intubation was made swiftly and accepted after only a brief and token resistance. The present study was undertaken partly as a result of a controversy brought about by our assertion that the anaesthetist could not administer proper anaesthesia and assist the surgeon as well. More important, it was done in an effort to assess critically a variety of techniques for a common but difficult procedure performed on otherwise healthy children.

MATERIAL AND METHODS

All children in this study were free of infection and healthy in every respect other than in having histories which were considered to indicate adenotonsillectomy. The results in 146 children were analysed.

A standard pre-anaesthetic medication was used: meperidine 1 mg/kg given intramuscularly one hour preoperatively together with atropine in the following doses: 0.3 mg for children under 3 years of age, 0.4 mg for children between 4 and 10 years of age, and 0.6 mg for older children. The effect of this medication was assessed by arterial sampling just before induction of anaesthesia, and the results were compared with findings in unpremedicated controls. There were 30 children in the premedicated group and 11 controls.

Techniques of induction of anaesthesia conformed with our usual practices and were as uniform as possible. Children under school age (a milestone of increased self-reliance and courage) were generally given rectal thiopental, approximately 12.5 mg/lb (27.5 mg/kg) body weight, about 20 minutes before surgery. The effect of this on the pH, $p\text{CO}_2$, and standard bicarbonate was assessed in a few patients by "heel-stick." This method of sampling capillary blood by stab, from the warmed heel, gives results in small children and infants which correlate well with arterial levels.² In the few spot-cases where we did this, the $p\text{CO}_2$ and pH

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were found to be little different from the arterial levels in other premedicated patients who did not receive rectal thiopental. However, in case this might be a factor of importance, the distribution of those who received rectal thiopental throughout the various groups was recorded, this is mentioned later. These particular children were brought into the operating room asleep and were induced with cyclopropane or halothane and intubated following paralysis with intravenous succinylcholine. Older children were brought into the operating room awake and induced with intravenous thiopental, 2.5 per cent solution, 25 mg per year of age, and succinylcholine. The doses of relaxant are detailed later.

Anaesthesia was conducted entirely by two residents, with the advice and assistance and under the supervision of a staff anaesthetist. Clinically, all these cases were well conducted, with one possible exception to be mentioned. No patient was included in whom any departure from our usual routine was made for example, when induction was deliberately prolonged to demonstrate endotracheal intubation to paediatric residents. Our object was to assess good clinical anaesthesia, well conducted, using a variety of agents and techniques.

AGENTS AND TECHNIQUES

The following agents and techniques were used

- 1 Nitrous oxide, oxygen (equal flow rates), and ether by endotracheal tube with spontaneous respiration (subsequently this will be referred to as Technique A) There were 28 patients in this group

- 2 Nitrous oxide, oxygen (equal flow rates), and methoxyflurane by endotracheal tube, with spontaneous respiration (subsequently called Technique B) There were 25 patients in this group

- 3 Oxygen and halothane, by endotracheal tube with spontaneous respiration (Technique C) There were 32 patients in this group

- 4 Oxygen and halothane by endotracheal tube with manually controlled respiration (Technique D) There were 20 patients in this group

- 5 Nitrous oxide and oxygen (precisely 75% to 25%) by endotracheal tube with manually controlled respiration, using intermittent succinylcholine (Technique E) There were 31 patients in this group

- 6 Nitrous oxide and oxygen (equal flow rates) or oxygen only with ether by insufflation for maintenance, without endotracheal intubation (Technique F) There were 10 patients in this group

Non-rebreathing techniques were used in all cases, flow rates of gases throughout being at least three times the calculated minute volume. A T-piece technique was used in the smaller children (up to five or six years of age), the expiratory limb having a non-distended volume of approximately 100 ml. A half-litre, open-tailed bag was attached to the end of this limb, to serve as an indicator of respiratory activity, when breathing was spontaneous, and to facilitate assisted or controlled respiration when this was needed, or was done by choice. The use of such a device does not upset the fundamental physical characteristics or the efficiency of the T-piece technique, provided that an adequate flow rate of gases is used, and that the bag does not become grossly distended. The expiratory

orifice must be no narrower than the internal diameter of the endotracheal tube used. These precautions were observed. For larger children, the Stephen-Slater non-rebreathing valve was used.

Ether was given from the vaporizer of the Airmed machine—Marks 1 and 2 (Technique A)—and methoxyflurane was given by the same vaporizer (Technique B). Neither inspired percentages of vapours nor blood gas contents were measured, but the closely observing staff anaesthetist did not consider the patients to be unduly depressed with these two agents. Our residents generally seem to err on the side of having patients too light for this procedure. With both agents, postoperative recovery was quick.

Halothane was given from the Fluotec vaporizer. Inspired concentrations of 2.5–3 per cent are often needed to settle children for this operation, 2–2.5 per cent being used for maintenance with spontaneous respiration (Technique C). On the other hand, when respiration was controlled (Technique D), considerably less halothane was needed, usually 1–1.5 per cent for maintenance. Blood pressure levels of 85–90 mm Hg were usual. With Technique D the patient was not allowed to breathe spontaneously until the operation had ended. However, no deliberate attempt at hyperventilation was made.

For the technique of 75 per cent nitrous oxide with 25 per cent oxygen and controlled respiration with intermittent succinylcholine (Technique E), a scalp vein needle was inserted in a vein on the dorsum of the hand or foot during induction, and the intubation and subsequent doses of succinylcholine were given through it.

For expert intubation a dose of 1 mg/4 lb body weight is quite enough in children, but for the residents slightly more, 1 mg/3 lb, was given. Intermittent doses were administered in small and frequent increments to achieve as accurate a titration as possible. The dose employed was 1 mg/8–10 lb body weight approximately every two minutes. The required time interval was noted exactly for the first one or two injections, this interval was found to remain remarkably constant, usually two minutes with these minimal doses for the duration of this procedure (20–30 minutes). Those who have advocated this technique invariably appear to use far too much succinylcholine, which is not an entirely innocuous fault.³ The flow rates of nitrous oxide and oxygen were set with scrupulous accuracy to give precisely 75 per cent and 25 per cent respectively. Provided that a dose of succinylcholine was not missed and control of ventilation therefore lost, these patients appeared adequately anaesthetized. The pupils were centrally fixed and small. The systolic blood pressure was notably higher than with other techniques, being usually around 110–115 mm Hg. If muscle relaxation is allowed to wear off, chaos will descend on the scene: the pupils become widely dilated, the pulse rate accelerates, movement becomes a problem, and it is with difficulty that normal operating conditions are restored.

Although this technique was conducted in the most expert fashion, there are three noteworthy observations to be made. First, slowing of the heartbeat occurs almost invariably. This is quickly detected by the precordial stethoscope. Those who have failed to record this just have not observed closely enough. It is usually a very transient event, coming on 10–15 seconds after injection, and disappearing

within another 30 seconds. Secondly, increased salivation was obvious to the observing staff anaesthetist, though none of the operators complained. Thirdly, controlled respiration can lead to some bubbling in the pharynx and this was commented on by one surgeon, it is obvious that this would hardly occur if adequate suctioning were being done. Recovery from this technique (E) is strikingly rapid.

When ether insufflation was to be used (Technique F), patients were deeply anaesthetized (pupils three-quarters dilated) before insertion of the mouth gag.

In all these cases the resident understood clearly that he was in charge of the anaesthetic, while the staff anaesthetist conducted the investigative procedure. The senior anaesthetist of the team also assisted and advised when needed and carefully supervised at all times. Precordial monitoring was carried out continuously by the resident, the staff anaesthetist keeping a close record of the blood pressure. Arterial cannulation and sampling was done by the staff anaesthetist.

TIMES OF SAMPLING

Ideally there are at least six times when arterial samples would be desirable for all patients: before pre-anaesthetic medication, after medication and just before surgery, immediately after induction and endotracheal intubation, during anaesthesia when the patient had reached a steady state, very soon after extubation, and at a later point in the recovery room. It was not technically possible to do this and, in general, samples were taken during and immediately after anaesthesia in the operating room and recovery room. The effect of pre-anaesthetic medication was assessed separately.

In the early part of the investigation an attempt was made to get arterial blood samples just after induction and endotracheal intubation. Our interest in this was heightened by finding one arterial carbon dioxide tension of 133 mm Hg, in a patient who was struggling at this point. Although we were never able to reproduce this finding, the suspicion remains that high levels of arterial carbon dioxide may occur under these circumstances. This elevation could not be due to apnoea alone, since at the currently accepted maximum rate of rise of 6 mm Hg/min apnoea⁴ the time interval is too short, but might be due to the sudden return of violent muscular activity before adequate ventilation has been begun. Since even a few squeezes of the bag reduce the level of arterial $p\text{CO}_2$ markedly, it is difficult to get this exact moment, which undoubtedly represents a very unsteady state. Two samples were drawn, however, during anaesthesia, one as early as possible after induction and one at the end of surgery. After 40 patients had been thus sampled, it was found that there was no great difference between these two, and so for the remainder of the series only one sample was taken during maintenance. This specimen was taken at the end of the procedure before anaesthesia was lightened.

Some of the postoperative specimens were taken in the immediate postintubation phase, while others were taken, especially in the early part of the investigation, in the recovery room. Before extubation all patients were flushed with 100

per cent oxygen, until the patient was reacting vigorously, and after adequate suctioning, the endotracheal tube was removed during inspiration. Because of the obvious rapidity of the fall in arterial oxygen tensions, the time interval from the moment of extubation to the end of sampling was recorded by stop-watch in 20 patients.

In all cases samples were drawn from the radial or femoral artery using a number 23 scalp-vein needle or a number 22 disposable needle, connected by a short length of plastic tubing to a 10 ml syringe containing a heparin-saline solution. At first a 0.1 per cent concentration of heparin was used, but on the faint suspicion that bleeding might have been increased, this was reduced to 0.05 per cent. Minimal amounts were used, seldom more than 2 ml of this solution in all, to keep the arterial needle open.

Three to five millilitres of blood were drawn under anaerobic conditions on each occasion and the sealed syringes sent to the respiratory laboratory for immediate analyses, which were done in the following manner. The arterial pH and $p\text{CO}_2$ were determined by the method of Astrup, and the standard bicarbonate derived from the nomogram of Astrup. A Clark oxygen electrode (Beckman Instruments) was used to measure the arterial oxygen tensions.

RESULTS AND DISCUSSION

The effect of the pre-anaesthetic medication, previously described, is shown in Table I and Figure 1. It will be noted that analysis of the results shows no

TABLE I
ARTERIAL BLOOD SAMPLES,
EFFECT OF PRE-ANAESTHETIC MEDICATION

	pH (units)	$p\text{CO}_2$ (mm Hg)	$p\text{O}_2$ (mm Hg)	Standard bicarbonated (mEq /L)
Unpremedicated controls (11)	7.40 (± 0.03)	35 (± 7)	92 (± 4.3)	22.2 (± 2.1)
Premedicated patients (30)	7.35 (± 0.06)	40 (± 6)	89 (± 7.3)	21.9 (± 1.9)
Significance	$t = 0.325$ $P < 0.80$	$t = 2.024$ $0.05 < P < 0.10$	$t = 1.571$ $P < 0.20$	$t = 1.215$ $P < 0.30$

Summary None of these differences are significant at the 5 per cent level or less. Mean age of controls = 12 years. Mean age of premedicated patients = 12 years. Mean time of sampling after pre-anaesthetic medication = 57 minutes.

significant difference, at an acceptable statistical level, in the four parameters measured, between premedicated and unpremedicated children. However, premedicated children showed a rise in arterial $p\text{CO}_2$, which though not significant at the 5 per cent level was significant at approximately the 6 per cent level. The chances of this being due to chance alone could therefore be considered to be less than six in a hundred.

It is worth noting that pre-anaesthetic medication had no significant effect in lowering arterial oxygen tensions, unlike the findings attributed to atropine pre-

EFFECT OF PREANAESTHETIC MEDICATION ON ARTERIAL BLOOD GASES

UNPREMEDICATED CONTROLS PREMEDITATED PATIENTS

FIGURE 1

medication in another report,⁵ admittedly based on a very different type of population

The results compiled for Techniques A to E inclusive were subjected to an analysis of variances. In this way it was possible to show at once that there were no significant differences in the arterial pH values of the samples taken after anaesthesia ($F = 1.39$, $P > 0.10$). Nor were there significant differences in the standard bicarbonate measurements during anaesthesia ($F = 1.42$, $P > 0.10$), or after anaesthesia ($F = 1.23$, $P > 0.10$), in a comparison of one technique with another.

The means and standard deviations of the arterial pH, pCO₂, and standard bicarbonate values of samples taken during anaesthesia are listed together in Table II and those taken after anaesthesia in Table III. The means and standard deviations of arterial oxygen tensions, both of the samples taken during anaesthesia and of those taken after extubation, are listed together for comparison and contrast in Table IV. The results for all these techniques are summarized in Figure 2.

There were significant differences in certain of the parameters measured during anaesthesia. The arterial carbon dioxide tensions of patients receiving nitrous oxide, oxygen, and ether, with spontaneous respiration (Technique A) (mean value 43 mm Hg $\pm$ 11), were the lowest of all patients who were allowed to breathe without assistance, and were, in fact, comparable with the values for those who were controlled with oxygen and halothane (Technique D). The mean arterial carbon dioxide tension of this latter group was 38 mm Hg ($\pm$ 8), and

TABLE II
MEANS OF ARTERIAL SAMPLES TAKEN DURING ANAESTHESIA FOR TECHNIQUES A TO E

	A (28)	B (25)	C (32)	D (20)	E (31)
pH (units)	7.34 (± 0.06)	7.28 (± 0.06)	7.25 (± 0.05)	7.38 (± 0.08)	7.43 (± 0.13)
pCO ₂ (mm Hg)	43 (± 11)	54 (± 12)	56 (± 10)	38 (± 8)	31 (± 5)
Standard bicarbonate (mEq/L)	21.5 (± 1.7)	21.4 (± 1.4)	20.8 (± 1.6)	21.7 (± 1.4)	20.9 (± 1.6)

TABLE III
MEANS OF ARTERIAL SAMPLES TAKEN IMMEDIATELY AFTER ANAESTHESIA FOR TECHNIQUES A TO E

	A (24)	B (17)	C (26)	D (17)	E (25)
pH (units)	7.33 (± 0.05)	7.30 (± 0.22)	7.27 (± 0.01)	7.28 (± 0.03)	7.35 (± 0.06)
pCO ₂ (mm Hg)	41 (± 6)	50 (± 14)	48 (± 12)	48 (± 5)	39 (± 7)
Standard bicarbonate (mEq/L)	20.7 (± 1.5)	21.5 (± 1.3)	20.6 (± 1.4)	20.7 (± 1.4)	20.7 (± 1.6)

TABLE IV
MEANS OF ARTERIAL OXYGEN TENSIONS (mm Hg), TECHNIQUES A TO E

	A (21)	B (24)	C (32)	D (14)	E (32)
During anaesthesia	220 (± 84)	194 (± 97)	360 (± 113)	419 (± 84)	121 (± 18)
After anaesthesia	87 (± 11)	82 (± 20)	88 (± 31)	78 (± 28)	88 (± 22)

the difference between Techniques A and D was not significant at the 5 per cent level ($t = 1.852, 0.05 < P < 0.10$)

There was no significant difference in arterial carbon dioxide levels when methoxyflurane (mean 54 mm Hg ± 12) or halothane (mean 56 mm Hg ± 10) was used with spontaneous respiration, but these levels were all significantly higher ($P \leq 0.001$) than those resulting from any other technique or agent tested. This degree of moderate hypercarbia is probably common during anaesthesia. In the otherwise healthy and well-oxygenated patient undergoing procedures of short duration it may be of little consequence except in so far as increased bleeding is concerned. This latter point is one of considerable importance. It was difficult for us to assess this, surgery was done by a large number of operators, which did not, therefore, give us a good opportunity to assess one technique at length against another. In addition certain other factors, such as the time lapse since the last bout of infection, and the variation in surgical technique employed with different operators, are uncontrollable and will always make it difficult in our practice to assess differences in blood loss.

FIGURE 2

The arterial carbon dioxide tension of those who had controlled respiration with 75 per cent nitrous oxide, 25 per cent oxygen, and intermittent succinylcholine (Technique E) was by far the lowest in the group (mean 31 mm Hg ± 5), being significantly lower than for those who were controlled with halothane and oxygen. Hyperventilation is probably an essential part of this technique.

The percentage of patients in each group who received rectal thiopental was as follows: Technique A, 50 per cent, Technique B, 48 per cent, Technique C, 25 per cent, Technique D, 30 per cent, Technique E, 50 per cent. From this distribution through the various groups, it seems safe to assume that rectal thiopental did not contribute to the differences between the means of arterial carbon dioxide values during anaesthesia. It should be clearly stated, however, that apart from the few spot checks by "heel-stick" mentioned previously, we did not determine in this study whether rectal thiopental does, in fact, significantly alter the arterial blood gas findings following pre-anaesthetic medication.

The pH values varied with the arterial carbon dioxide tensions, showing the same statistical differences, with variations in degree only. Thus the pH difference was less than the pCO₂ difference between ether and methoxyflurane ($P < 0.01$ compared with $P < 0.001$), about the same when halothane with spontaneous respiration was compared with halothane using controlled respiration ($P < 0.001$ in both cases), and the pH difference was less than the pCO₂ difference when halo-

thane with controlled respiration was compared with nitrous oxide, oxygen, and controlled respiration using succinylcholine ($P < 0.05$ and $P < 0.02$ respectively, Table V) An interesting point for speculation is the difference in standard

TABLE V
SIGNIFICANCE OF DIFFERENCES OF ARTERIAL BLOOD GAS SAMPLED DURING ANAESTHESIA FOR TECHNIQUES A TO D

	A against B	B against C	C against D	A against D	D against E
pH	$t = 2.941$ $P < 0.01$	$t = 1.523$ $0.10 < P < 0.20$	$t = 6.5$ $P < < < 0.001$	$t = 1.852$ $0.05 < P < 0.1$	$t = 2.37$ $P < 0.05$
$p\text{CO}_2$	$t = 4.199$ $P < < 0.001$	$t = 0.674$ $P < 0.6$	$t = 6.64$ $P < < < 0.001$	$t = 1.805$ $0.05 < P < 0.10$	$t = 2.56$ $P < 0.02$

Summary There are significant differences in both pH and $p\text{CO}_2$ values of techniques A against B, C against D, and D against E. None of these values are significantly different in the other techniques compared at the 5 per cent level or less.

bicarbonate levels in the two techniques of controlled respiration. As pointed out earlier, there is no statistical difference between the standard bicarbonate levels of the five Techniques A to E, when compared against each other during anaesthesia, or against one another in the post-anaesthesia samples. However, although the pH when respiration was controlled with succinylcholine was significantly higher than the pH when respiration was controlled with halothane-oxygen (means 7.43 ± 0.13 compared with 7.38 ± 0.08), the standard bicarbonate levels varied in the opposite direction (Table II). One wonders if the metabolic acidosis which is said to occur with hyperventilation techniques was already beginning to appear after as brief a period as 20–30 minutes.

In the post-anaesthetic period the differences in arterial carbon dioxide tensions for patients anaesthetized with different techniques tend to disappear (Table III). However, there are still markedly significant differences, and the findings following the technique of controlled respiration with halothane and oxygen are particularly noteworthy. The general tendency is a return towards normal, following withdrawal of anaesthesia. In the case of halothane-oxygen with controlled respiration (Technique D) an "over-shoot" was obvious. The patients who had ether with spontaneous respiration were, in fact, doing better when the results were statistically analyzed (Table VI). This is perhaps not surprising from the clinical picture of depressed respiration which was seen following halo-

TABLE VI
SIGNIFICANCE OF DIFFERENCES IN $p\text{CO}_2$ VALUES OF ARTERIAL BLOOD SAMPLES TAKEN IMMEDIATELY AFTER ANAESTHESIA FOR TECHNIQUES A TO E

	A against B	B against C	A against D	D against E
$p\text{CO}_2$	$t = 3.00$ $P < 0.01$	$t = 0.678$ $P < 0.60$	$t = 2.333$ $P < 0.05$	$t = 3.02$ $P < 0.01$

Summary There are significant differences between $p\text{CO}_2$ values of techniques A against B, A against D, and D against E. None of the other differences are significant at the 5 per cent level or less.

thane with controlled respiration. In fact, it probably means simply that respiration was not assisted or controlled for an adequate length of time after withdrawal of anaesthesia and before extubation. Tissue saturation with halothane when respiration is controlled, even with low concentrations, is very much higher than when the self-limiting factor of spontaneous respiration is in play. The percentage vaporizer can cause a dangerous delusion in the administrator.

The mean values of the arterial oxygen tensions during anaesthesia (Table IV) varied widely as expected. In only one technique was the percentage of oxygen (25%) kept constant throughout. Two points of interest emerge here. The standard deviation (± 18 mm Hg) was by far the lowest, as might have been predicted. Perhaps more interesting, in view of recent work, was the finding that the mean arterial oxygen tension was 121 mm Hg. Respiration was manually controlled, and hyperventilation was employed, two factors which would tend to correct the arterial hypoxaemia said to occur with some mechanical ventilators.⁶ In addition, the population we sampled was a young and healthy one. The population from whom samples taken during controlled respiration with 25 per cent oxygen and 75 per cent nitrous oxide were reported to show arterial oxygen tensions well below 100 mm Hg might have been expected to suffer from chronic low-grade pulmonary infections, and had a mean age of 54 years.⁷

The mean values of the arterial oxygen tensions of the samples taken after anaesthesia are remarkably close, but show wide standard deviations (Table IV). A comparison of these figures with the arterial oxygen tensions of premedicated patients sampled just before anaesthesia shows no statistical difference (Table VII). It is worth observing that the lowest value is found once more in patients

TABLE VII

SIGNIFICANCE OF DIFFERENCES BETWEEN ARTERIAL OXYGEN TENSIONS MEASURED IMMEDIATELY AFTER ANAESTHESIA AND THOSE OF PREMEDICATED PATIENTS IMMEDIATELY BEFORE ANAESTHESIA FOR VARIOUS TECHNIQUES

	"Before" against A	"Before" against B	"Before" against D
pO_2	$t = 0.735$	$t = 1.359$	$t = 1.275$
	$0.40 < P < 0.50$	$0.10 < P < 0.20$	$0.20 < P < 0.30$

Summary The differences between the arterial oxygen tensions measured immediately after techniques A, B, C, D, and E and those of premedicated patients measured immediately before anaesthesia are not significant at the 10 per cent level or less.

who received halothane-oxygen with controlled respiration. These particular findings must be accepted with some caution. The immediate post-anaesthetic state is, by its nature, unsteady and difficult to control. The rapidity with which arterial oxygen tensions fall is illustrated in Figure 3. All patients received 100 per cent oxygen for some minutes before extubation so that in fact the slope of fall must have been steeper than shown. In general, arterial samples had been drawn before 120 seconds had passed. We often may not realize how rapidly we are abandoning our patients to their own devices. The continuation of oxygen by face mask in the post-anaesthetic period is obviously a good precaution. None of the patients sampled had any airway obstruction or laryngeal spasm. It is clear

that arterial oxygen tensions might fall dangerously low and precipitously in the presence of such complications. An illustration of the effect of suctioning vigorously in the recovery room is also shown in Figure 3. Too often this exercise is a futile and possibly dangerous routine. Without doubt all clots and fresh bleeding should be removed at once, but such a method should not be used freely without a knowledge of the possible dangers involved and without an oxygen mask always at hand.

All the findings in the small group who were given insufflation ether for maintenance, without endotracheal intubation (Technique F), are shown in Table VIII, and Figure 4. No statistical analysis was attempted but it appears

TABLE VIII
ARTERIAL SAMPLES TECHNIQUE F INSUFFLATION ETHER ANAESTHESIA

	pH (units)	pCO_2 (mm. Hg)	pO_2 (mm Hg)	Standard bicarbonate (mEq /L)
During anaesthesia	7.34 (± 0.06)	39 (± 9)	172 (± 90)	20.8 (± 1.2)
Immediately after anaesthesia	7.36 (± 0.04)	38 (± 8)	91 (± 27)	21.1 (± 0.4)

Because of the smallness of the group no statistical analysis of differences, compared with other groups, is offered. On inspection, these results are the most nearly normal, when compared with immediate pre-anaesthetic findings, of any technique studied.

FIGURE 4

that these findings, if representative, show the least change from pre-anaesthetic levels of any technique tried, and this in spite of lack of practice on our part. No condemnation of this time-honoured routine emerges from these few arterial blood gas studies, but there appear to us to be other reasons why endotracheal intubation is generally safer. Soiling of the tracheobronchial tree with blood is very common when no tube is used⁸ and laryngeal irritation is apparently no less than following intubation¹

OBSERVATIONS IN THE RECOVERY ROOM

The patients who were allowed to breathe spontaneously with halothane or methoxyflurane emerged rapidly and were difficult to manage, thrashing around and often requiring restraint in the recovery room. There was no analgesic effect evident to us following methoxyflurane. The demented behaviour of some of these children, especially those who had received halothane, did not contribute to good care. Those who received ether generally required less sedation, though

they tended to be the most nauseated. They were the most satisfactory of all those who had been allowed to breathe spontaneously, from the point of view of manageability.

The children who had controlled respiration with 25 per cent oxygen and 75 per cent nitrous oxide, using intermittent succinylcholine, presented a strikingly different picture from all others in the recovery room. They were conscious and rational, and although they complained frequently of pain (in an intelligent and intelligible manner) they responded well to comforting words and actions. This was in contrast to the others, with many of whom verbal communication could never be established. Many of those who were controlled with nitrous oxide-oxygen-succinylcholine required narcotics for relief of pain. It was felt that bleeding in the recovery room was less in these patients than in any others.

This technique demands, perhaps, a high standard of skill and care, but the results place it in a class by itself, and those who first described it⁹ are to be commended.

SUMMARY AND CONCLUSIONS

As a base line, the effect of pre-anaesthetic medication on the arterial blood gases was compared with normal, unpremedicated controls. Meperidine and atropine given together by intramuscular injection, about one hour before sampling, were found to cause no significant alteration in arterial pO_2 , pH, or standard bicarbonate. There was a rise in arterial pCO_2 which was only significant at approximately the 6 per cent level.

The results of arterial blood samples taken during and after adenotonsillectomy, using six different techniques of anaesthesia, have been presented and analysed. When endotracheal intubation was used and respiration was spontaneous, ether resulted in the most normal ventilation. Methoxyflurane and halothane, with spontaneous respiration, caused a significant elevation of arterial pCO_2 and hypoventilation. It is not suggested that statistical significance and clinical importance necessarily correspond, but the effect of hypercarbia on the amount of bleeding during this difficult operation should be considered.

Controlled respiration with halothane-oxygen, or nitrous oxide-oxygen (75% 25%) and succinylcholine, caused significantly lower arterial pCO_2 levels and higher pH levels. These differences continued in the postoperative period, except that the halothane-oxygen-controlled respiration group tended to have a period of depressed respiration after extubation, probably as a result of clinical miscalculation. This was shown by a marked rise in arterial pCO_2 and the lowest arterial pO_2 level of all the techniques at this time.

Arterial oxygen tensions during anaesthesia varied widely but were all well above 100 mm Hg. With 75 per cent nitrous oxide and 25 per cent oxygen using manually controlled respiration with succinylcholine, the mean arterial pO_2 was 121 mm Hg (± 18), and this technique, properly carried out, was considered safe in children.

Very steep and rapid falls in arterial oxygen tensions occurred in the immediate post-anaesthesia period in all cases in the absence of any obstruction. This is a

very dangerous period and oxygen should be given routinely to all patients both at this time and when suctioning is done in the recovery room

The results with the technique of ether insufflation, because of the smallness of the group, are considered separately. If the technique is clinically well done, the arterial blood gases are apparently quite within normal range. However, the lack of control of the airway and the very common finding of blood in the tracheo-bronchial tree post-operatively, when this technique is employed, are thought to make it less desirable than the proper use of endotracheal intubation.

Many of these children are difficult to manage in the recovery room. The patients who had 75 per cent nitrous oxide, 25 per cent oxygen, and controlled respiration with succinylcholine are strikingly easier to manage and generally have less bleeding at this time.

It is quite clear that the anaesthetist must devote all his attention to his proper task during this procedure. The practice of assisting the surgeon as well can only be described as unreasonable and dangerous.

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RÉSUMÉ

Comme point de départ, disons que l'effet de la médication préanesthésique sur les gaz du sang artériel a été étudié en regard de témoins normaux non pré-médiqués. La mépéridine et l'atropine données ensemble en injection intramusculaire, environ une heure avant le prélèvement du sang, n'ont produit aucune modification importante dans la pO_2 artérielle, le pH et les bicarbonates. Nous avons noté une élévation de la pCO_2 artérielle que l'on a considérée importante seulement si elle approchait du niveau de 6 pour cent.

Nous avons analysé et présenté les résultats des échantillons de sang artériel prélevés pendant et après les amygdalectomies et l'ablation de végétations adénoïdes pour lesquelles nous avons employé six différentes techniques d'anesthésie. Chez un malade intubé, respirant spontanément, l'éther maintenait la plus normale des ventilations. Le méthoxyfluane et l'halothane, chez un malade en respiration spontanée, entraînaient de l'hypoventilation et une élévation marquée de la pCO_2 artérielle. Nous ne voulons pas laisser entendre que cette élévation

ait une signification statistique et que, nécessairement, elle prenne une importance clinique, mais l'effet de l'hypercarbie sur la perte de sang au cours de cette opération difficile est un facteur à retenir

La respiration contrôlée avec halothane-oxygène, ou protoxyde d'azote-oxygène (75%-25%) et succinylcholine a entraîné des niveaux de $p\text{CO}_2$ artérielle plus bas et des niveaux de pH plus élevés. On a continué d'observer ces différences au cours des suites opératoires à l'exception du groupe où l'on fait usage de l'halothane-oxygène et de la respiration contrôlée, ces malades ont eu tendance, après l'extubation, à présenter une respiration déprimée probablement à cause d'une mauvaise évaluation clinique. La preuve est qu'on a observé une élévation marquée de la $p\text{CO}_2$ artérielle et le plus bas niveau de $p\text{O}_2$ artérielle parmi toutes les techniques que nous avons utilisées.

Au cours de l'anesthésie, la tension artérielle d'oxygène a été très variable, mais elle est toujours demeurée bien au-dessus de 100 mm Hg. Lorsque l'on faisait usage de 75 pour cent de protoxyde d'azote et 25 pour cent d'oxygène, de la respiration contrôlée manuellement et de la succinylcholine, la $p\text{O}_2$ artérielle a été en moyenne de 121 mm Hg (± 18) et cette technique, bien exécutée, demeure de toute sécurité chez les enfants. Chez tous les malades, immédiatement après l'anesthésie, nous avons observé des chutes rapides et prononcées de la tension d'oxygène dans le sang artériel et cela, en l'absence de toute obstruction. Cette période est très dangereuse et l'on devrait donner, de routine, de l'oxygène à ce moment-là et au cours des succions à la salle de réveil.

Les résultats obtenus avec la technique d'insufflation d'éther, à cause du petit nombre de malades, sont mis à part. Si, cliniquement, la technique est bien appliquée, les gaz du sang artériel demeurent apparemment tout à fait dans la moyenne normale.

Toutefois, le manque de contrôle sur la respiration et la découverte fréquente de sang dans les voies respiratoires après l'opération, à la suite de l'usage de cette technique, nous font opter pour la technique de l'intubation endotrachéale.

Plusieurs de ces enfants sont difficiles à manier à la salle de réveil. Ceux qui ont reçu le mélange protoxyde-oxygène (75%-25%) avec respiration contrôlée et succinylcholine sont beaucoup plus faciles à manier et généralement, à ce stade, ils perdent beaucoup moins de sang.

Il est parfaitement clair que, durant ces opérations, l'anesthésiste doit porter toute son attention à son propre travail, on ne peut qualifier que déraisonnable et dangereuse la pratique, pour l'anesthésiste, d'assister le chirurgien.

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