ANAESTHESIA FOR CARDIAC CATHETERIZATION AND ANGIOCARDIOGRAPHY IN CHILDREN*

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VARIOUS METHODS have evolved over the years to handle the specific problems of anaesthesia for infants and children undergoing diagnostic heart catheterization. It is generally agreed that some form of general sedation or anaesthesia is necessary. Virtually all forms of anaesthesia have been used. General anaesthesia is recommended by some^{1,2,4,8,10,11,15} whereas ataractic^{3,12,13} and other forms of sedation are equally popular.^{5,6,7,9,14}

At the Vancouver General Hospital the paediatric cardiologists request general anaesthesia for all small infants and for older children where angiocardiology is to be performed. The problems of general anaesthesia for this procedure are well known.^{1,2,11,15} These basically revolve around the use of X-ray and electronic monitoring equipment precluding the use of an inflammable agent. Many of these children are severely and chronically ill and a technique is chosen that will cause minimal upset to their cardiopulmonary dynamics.

Some congenital cardiac anomalies, if untreated, carry a high mortality in infancy. Recent improvements in operative techniques make earlier surgical intervention feasible. There is a trend for earlier and more extensive investigation in the very young to ensure an accurate diagnosis. The following is a description of a suitable method of anaesthesia for diagnostic heart catheterization using halothane and nitrous oxide and, where necessary, halothane and air.

METHODS

1. *Premedication*

It has been found unnecessary to give anticholinergic drugs preoperatively. Halothane is non-irritating and secretions, therefore, are not a problem. To avoid respiratory depression morphine-like derivatives are also avoided.¹⁹ Hence these children receive no premedication.

2. *Induction*

Induction with the nitrous oxide-halothane technique is usually uneventful and with experienced anaesthetists excitement is not evident.

3. *Maintenance*

A simple technique is used employing a high flow with a bag and mask of appropriate size. The flow commonly used is 4 litres of nitrous oxide and 2 litres

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FIGURE 1 Infant in position for biplane cineradiography

of oxygen delivered from an Ohio Vernitrol vaporizer (cf. Fig. 1). Intubation has been found not to be necessary and airways are avoided. Hence a very light plane of general anaesthesia can be maintained. The discomfort of venostomy is obtunded further by the prior infiltration of 1 per cent lignocaine.

Where oxygen saturations are to be measured the nitrous oxide and oxygen are discontinued, and a 6 litre flow of air is substituted. The air tank is connected to one of the oxygen inlets of the anaesthetic machine. The patient continues to receive a suitable concentration of halothane. After 5 minutes a steady state is assumed and oxygen saturation determinations are carried out. Following these, anaesthesia is resumed with nitrous oxide and halothane.

Just prior to the actual cineradiography the patient is given halothane and 100 per cent oxygen. Immediately after this procedure nitrous oxide is again included in the anaesthetic mixture.

4. *Monitoring*

Cardiac activity is monitored initially with a precordial stethoscope. Usually a vectorcardiograph is taken before the patient is connected to a standard E.C.G. lead on the multichannel recorder.

Blood loss is measured directly as samples are taken. Small, very anaemic, infants are cross-matched preoperatively.

Rectal temperature is recorded intermittently on those children under 20 pounds.

5. *Postoperatively*

Patients anaesthetized in the manner described are awake and moving within minutes after the end of the procedure. They proceed nevertheless to the post-anaesthetic recovery room, where they are further observed. If a high oxygen atmosphere was necessary preoperatively, it is continued at this time.

RESULTS

One hundred cases anaesthetized in the manner described were selected at random from procedures done in the past 12 months.

TABLE I

1. Right heart catheterization	25
2. Right heart catheterization and angiocardiology*	38
3. Right heart catheterization and dye curves	7
4. Right heart catheterization and left heart catheterization and angiocardiology	22
5. Left heart catheterization	1
6. Left heart catheterization and right heart catheterization	5
7. Left heart catheterization and angiocardiology	2
	<hr/> 100

*Some of these patients had dye curves as well.

An analysis of the procedures is shown in Table I. Angiocardiology is used in this table to include both cineradiography and biplane-angiography. Sixty-two

of the above procedures therefore included angiocardiology. The average operating room time for the above procedures was 2 hours and 15 minutes.

The average age of the patients undergoing heart catheterization was 2 years and 8 months. The average weight was 24 pounds. The oldest patient in this series was 14 years of age whereas the youngest was but 2 days old. A breakdown of the patients by age group revealed that 50 per cent of the patients were below the age of one year and 40 per cent were below the age of 6 months.

A breakdown of the diagnosis as assisted by heart catheterization studies is as given in Table II.

Late in the series spot blood gas studies were done by the method of Astrup on a small number of patients, with the results given in Table III.

TABLE II

1. Normal	5
2. Ventricular septal defect	10
3. Ventricular septal defect plus pulmonary hypertension	7
4. Ventricular septal defect plus other lesions	9
5. Atrial septal defects	9
6. Atrial septal defects plus other malformations	7
7. Patent ductus	10
8. Coarctation	1
9. Pulmonary stenosis	6
10. Tetralogy of Fallot	7
11. Transposition	3
12. Atrial septal defect and ventricular septal defect	9
13. Eisenmenger's complex	1
14. Aortic valve disease	8
15. Epstein's malformation	1
16. Other malformations not listed in the above	7
	100

TABLE III

	Age	Time after onset of anaesthesia	pH	pCO ₂ (mm. Hg)	Standard bicarbonate (mEq./L.)	Base excess (mEq./L.)
(1)	12 years	1 hr.	7.350	49.8	24.1	+1.8
(2)	3 years	2 hr.	7.259	59.5	21.3	-2.2
(3)	2 months	2 hr.	7.210	50.2	17.2	-8.6
(4)	8 days	1½ hr.	7.313	42.7	20.3	-3.7
(5)	3½ months	2¼ hr.	7.218	52.0	18.5	-6.2
(6)	3½ years	1 hr. 25 min.	7.240	46.0	17.9	-7.1
Ave.	3 yr. 2 mo.	1 hr. 36 min.	7.265	50.0	19.9	-4.3
Normal range			7.35-7.45	34-46	21-25	±2.5

COMPLICATIONS

Generally, complications were minimal but the following were noted:

1. *Profound bradycardia.* Two patients developed a profound bradycardia following the injection of the radio-opaque dye. One patient received gr. 1/600 atropine intravenously and slowly improved with this therapy and oxygenation. No sequelae were observed in either patient.

2. *Cardiac tamponade.* One 4-week-old patient inadvertently received some radio-opaque dye into the pericardial sac. Cardiac embarrassment quickly followed, necessitating endotracheal intubation and the administration of 100 per cent oxygen. The pericardium was aspirated, the dye removed, and the patient quickly improved. There were no sequelae.

3. *Apnoea.* One 3-month-old patient became apnoeic after injection of dye for biplane cardiography. Treatment consisted of assisted respirations until spontaneous ventilation resumed. There were no sequelae.

4. *Ventricular fibrillation.* This 5½-year-old girl with Eisenmenger's complex developed tachycardia and later ventricular fibrillation after her second dye injection for a selective aortogram. External cardiac massage was immediately instituted and shortly thereafter she was defibrillated with one shock of 45 watt-seconds. Resuscitation also included the administration of 10 mEq. of sodium bicarbonate and 25 mg. of diphenylhydantoin sodium. Normal sinus rhythm was re-established and the patient woke up following the procedure with no untoward effects.

5. *Postoperative death.* This 34-day-old infant had a right heart catheterization, a left heart catheterization, and cineradiography. The operative time was 2 hours and 30 minutes. The diagnosis was a ventricular septal defect, a patent ductus arteriosus, pulmonary stenosis, and dextra-aorta. The patient arrived conscious in the post-anaesthetic room but one hour later began twitching and in spite of intensive therapy carried on to convulse and die. Rectal temperature on arrival in the P.A.R. was 92° F.

DISCUSSION

The cardiovascular disturbance produced by halothane anaesthesia is well known. It is agreed that hypotension is consistently produced,^{16,19,20} but there is often no consistent relationship to concentration.²⁰ Bradycardia occurs almost routinely, but it is also inconsistent in degree. Bradycardia, thought to be due to halothane, was seen occasionally in our series during induction, but it was never a problem. Hypotension likewise was not a prominent feature as judged by the intra-arterial pressure recordings. In one series cardiac output during halothane anaesthesia was not significantly altered.¹⁷

Respiration under halothane and air anaesthesia is described as usually smooth, quiet, and regular.¹⁶ Though respiratory depression is seen with halothane anaesthesia,¹⁹ this is minimal in the absence of premedication. In our series there was no clinical evidence of carbon dioxide retention. However, in a random check of the $p\text{CO}_2$ in a small number of our patients (see Table III) the average value was found to be slightly elevated at 50 mm. Hg. This possibly reflects a degree of respiratory depression and a minimal amount of rebreathing. This small elevation, however, is well below the threshold of $p\text{CO}_2$ needed before ventricular irritability or cardiac arrhythmias appear.²⁰

Where oxygen saturations are to be done, it is desirable to provide an atmospheric concentration of oxygen. Air has been used before with inhalational agents to meet this problem.^{2,11,15} In this series some patients were carried uneventfully on halothane and air for periods up to one hour. Oxygen saturation

was assumed to have reached equilibrium after a period of five minutes although it is known that a steady respiratory state takes somewhat longer to develop.¹⁸ Where arterial saturations were determined in the process of the investigation, all samples showed a 95 per cent or greater saturation in the absence of a right to left shunt.

For the past two years the radio-opaque medium has been sodium and methylglucamine diatrizoates (trade name—Renovist 69%). Advances in the safety of the dye have all but eliminated the problems of bronchospasm and other dangerous reactions to the drug which were more common in the past.¹⁰ It is, however, during or shortly after the injection of the dye that the anaesthetist has to be most vigilant. In our series all the operating room complications occurred following this procedure.

The use of muscle relaxants and the production of apnoea have not been found to be necessary for angiocardiology. Although full facilities are always available for immediate intubation, this is not done except on an emergency basis.

Where no airway or endotracheal tube is used, halothane concentrations can be kept between 0.5 and 1.0 per cent. Concentrations of up to 1.5 per cent are needed only at the time of induction. Thus the patient awakens quickly and with minimal disturbance at the end of the procedure.

It is noted that some of these patients (Table III) have a tendency towards metabolic acidosis. In one instance (patient No. 3) the acidosis was moderately severe. Unfortunately no pre-operative metabolic study was available for comparison. It is known, however, that some patients with severe cardiovascular disease have an associated metabolic acidosis.²¹

The mortality from angiocardiology in children has been quoted as ranging from 0.2 to 4.0 per cent.¹ It is certainly within the realm of the anaesthetist to help to keep this figure as low as possible.

SUMMARY

A simple anaesthetic technique has been described for use in cardiac catheterization and angiocardiology in children and infants. Halothane has been employed with nitrous oxide and air alternating as the carrier gas. The absence of premedication, airways, and endotracheal tubes allows a light general anaesthetic with fast recovery and minimal systemic disturbance.

RÉSUMÉ

Il est généralement admis qu'un certain degré de sédation générale ou d'anesthésie est nécessaire pour les enfants et pour les adolescents soumis à un cathétérisme cardiaque.

Les auteurs utilisent une technique simple, à grand débit, en se servant d'un ballon et d'un masque de grandeur appropriée. L'agent anesthésique principal est l'halothane, et l'induction est réalisée grâce au protoxyde d'azote et à l'halothane sans l'aide d'aucune prémédication. L'intubation n'a pas été jugée nécessaire, et les tubes pour assurer un conduit aérien efficace (*air-way*) ont

été mis de côté. Une anesthésie générale à un stade très léger peut alors être maintenue.

Quand arrive le moment de mesurer les saturations d'oxygène, le protoxyde d'azote et l'oxygène sont discontinués et un flot d'air de six litres est utilisé pour la distribution de l'halothane. Après cinq minutes, tout est stabilisé et on peut calculer la saturation d'oxygène.

Les calculs terminés, on reprend l'anesthésie au protoxyde et à l'halothane.

L'activité cardiaque est évaluée au début grâce au stéthoscope sur la région précordiale. Habituellement, on prend un vectocardiogramme avant que le malade ne soit relié à un appareil standard d'électrocardiographie.

La perte sanguine est évaluée directement à mesure que les échantillons sont prélevés, et la température rectale est contrôlée à intervalles réguliers chez les enfants au-dessous de 20 livres.

Les malades qui sont soumis à cette anesthésie sont réveillés et peuvent circuler quelques minutes après la fin de l'examen, mais ils sont néanmoins gardés sous observation à la salle de réveil.

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