# ANESTHESIA FOR CHILDREN UNDERGOING DIAGNOSTIC CARDIAC CATHETERIZATION *

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With the ever-increasing number of children undergoing cardiac surgery, increased accuracy in diagnosis is mandatory. Since cardiac catheterization was first done by Forssman in Germany in 1929 and subsequently developed in this country by Cournand and co-workers, many new techniques have been developed, and consequently an increasing number of children and infants are undergoing this diagnostic procedure. The purpose of the authors in this paper is to report the anesthetic methods used for cardiac catheterization and the results obtained to date at the Mayo Clinic since the first catheterization was carried out there in 1947.

In order to facilitate the catheterization procedure and to obtain data amenable to accurate interpretation, it is of the utmost importance that the patient remain quiet during the procedure. This is necessary since the interpretation of the significance of possible differences in pressures and oxygen saturation of blood samples taken from different chambers of the heart and the great vessels is facilitated greatly if the patient is in a steady state with constancy of arterial oxygen saturation and cardiac output. It is also necessary that the patient remain quiet so that indwelling needles in the radial or other arteries and veins remain in place. The anesthesia, however, should not be unnecessarily deep with consequent derangements of metabolism and cardiac output.

## Method

To illustrate the method used, let us assume that a 6 year old child weighing 40 pounds (about 18 kg.) is scheduled for catheterization.

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The child is noted to be moderately cyanotic and slightly underweight and has a history of tiring easily. A systolic murmur, grade 3, has been heard since birth maximally in the second and the third left interspaces and is transmitted over the entire precordium. The second pulmonic sound is accentuated. A roentgenogram shows an enlarged heart with prominence of the pulmonary-artery segment and the hilar vessels. Electrocardiographic tracings are indicative of right ventricular hypertrophy. The patient has been receiving digitalis for about three months. The clinical diagnosis is ventricular septal defect with pulmonary hypertension (Eisenmenger complex).

The child is admitted to the hospital the evening prior to the contemplated procedure and is evaluated by the pediatrician and the anesthesiologist at this time. Bedtime sedation consisting of ¾ gr. (about 0.05 Gm.) of pentobarbital sodium (Nembutal® sodium) is ordered along with other drugs when indicated such as digitalis and antibiotics. No food is permitted after midnight. In the morning, about one and a half hours prior to the catheterization, the patient is given a warm-water enema. This is followed in turn by ¾ gr. of pentobarbital sodium administered rectally and by moderately heavy premedication consisting of 1/24 gr. (about 0.0027 Gm.) of morphine sulfate administered subcutaneously. Restriction of the dosage of atropine sulfate (usually about 1 mg. of morphine per 10 pounds of body weight) has been advocated to avoid unnecessary tachycardia (1, 2).

The patient then is brought to the catheterization room and anesthetized with rectally administered tribromoethanol solution (Avertin®) (2.5 per cent) or rectally administered thiopental sodium (Pentothal® sodium) (10 per cent), the dose depending on the condition of the patient at the time. When adequate premedication has been given, a dosage of 100 mg. of tribromoethanol solution per kilogram of body weight has been most satisfactory. With the child asleep, venipuncture is done and a syringe containing diluted thiopental sodium (1.25 per cent) and a syringe containing isotonic saline solution are connected to the indwelling intravenous needle via a three-way stopcock or Y connection for use should supplementary anesthesia become necessary, as the effect of the tribromoethanol solution begins to wear off. Since venipuncture is done when the effect of the tribromoethanol solution is maximal, it is necessary to test the position and the patency of the needle with saline solution, since the use of even small amounts of thiopental sodium at this time may produce and, in fact, has produced respiratory arrest. Injection of supplementary thiopental sodium through an intravenous needle has been found superior to injection of supplementary thiopental sodium through the cardiac catheter, since it avoids possible contamination, inadvertent injection of air or other embolic material and the waste of time consequent to disconnecting the catheter for injection of thiopental sodium.

The use of hot towels has been suggested and employed to make accessible veins more easily visualized. It is important that the towels be applied correctly, as described by one of us [Lundy (3)]. The patient is then placed on the fluoroscopic table, and earpiece oximeters and electrocardiographic leads are connected. Local anesthesia (1 per cent procaine hydrochloride) is used at the site of insertion of the cardiac catheter into an antecubital vein or the saphenous vein below the groin. Size 4 or 5 French radiopaque catheters are used, varying in length from 50 to 100 cm., depending on the size of the child. The catheter is inserted through a special 15 or 16 gauge thin-walled needle (4) if the vein can be visualized readily or by means of a cutdown if this is not the case. If a large enough vein is available, insertion of the catheter through an arm vein is much preferred to the saphenous route because of greater success in entering the pulmonary artery when the arm veins are used. Specially ground 20 gauge needles also are inserted into the radial or the femoral arteries, or both, for the purpose of obtaining arterial blood samples and for reading intra-arterial blood pressure.

Endotracheal intubation of these children is not done routinely, but emergency equipment, consisting of oxygen, laryngoscopes, endotracheal tubes and suction apparatus, should always be easily accessible. A cart containing cardiac resuscitation equipment to be used in the event of ventricular fibrillation or cardiac arrest is kept constantly at hand, although its use has not been necessary in our series of children to date.

The use of the cuvette oximeter has eliminated the need for a multitude of Van Slyke analyses and consequently has reduced blood loss in these children. Blood loss has been reduced further by the practice of reinfusing, by the same route, the blood which is withdrawn via the catheter and passed through the cuvette oximeter for determination of blood-oxygen saturation. The blood withdrawn during the multiple dye-dilution studies frequently required for accurate diagnosis (5–7) also is reinfused via intra-arterial radial or femoral needles, or both, or via the catheter. With this technique, it has been possible to obtain with safety as many as 31 blood samples and 5 arterial dye-dilution curves during a cardiac catheterization of a 10 pound (about 4.5 kg.) infant. However, proper blood must be readily available so that if blood is needed it is at hand.

Blood pressure and oxygen saturation recordings from the different chambers of the heart, along with arterial dye-dilution curves, are made by means of a photo-oscillographic assembly (8) with the patient breathing either room air or 100 per cent oxygen. The rate of oxygen uptake is measured by connecting an oronasal mask to a spirometer during the period necessary for the recording. During these periods, respirations are recorded and monitored by means of a strain-gauge manometer which senses the pressure fluctuations in the airway during the phases of the respiratory cycle.

Since the catheterizations vary greatly in time and technical difficulty, the use of supplemental anesthesia has been necessary in the majority of cases, because many of these children have been anesthetized for periods of four to five hours. At the termination of the catheterization, the child is returned to his bed. Unless known allergy exists, penicillin (300,000 units) is given prophylactically. Oxygen tents are used when necessary and frequently prophylactically. Digitalis and other drugs are prescribed as needed. Since heparinized isotonic saline solution is used during the catheterization to flush the manometer systems, the child is also observed carefully for any increased bleeding tendency. The child's condition is checked frequently

TABLE 1

DIAGNOSES OF ANATOMIC DEFECTS FOR WHICH DIAGNOSTIC CARDIAC CATHETERIZATION WAS PERFORMED

| Anatomic Defects | Cases* |
|---|---|
| Atrial septal defect | 36 |
| Ventricular septal defect | 36 |
| Patent ductus arteriosus | 27 |
| Eisenmenger complex | 16 |
| Pulmonary stenosis | 36 |
| Tetralogy of Fallot | 10 |
| Coarctation of the aorta | 6 |
| Tricuspid atresia | 3 |
| Anomalous pulmonary venous connection | 5 |
| Transposition of great vessels | 4 |
| Ebstein's malformation | 2 |
| Idiopathic pulmonary hypertension | 2 |
| Miscellaneous | 12 |

* Combined lesions, such as pulmonary stenosis and atrial septal defect, are listed separately under each defect.

and no feedings are given until he is fully awake. The child usually can be dismissed from the hospital the same evening after the catheterization or on the following day.

## DATA

One hundred four children undergoing diagnostic cardiac catheterization at the Mayo Clinic have received anesthesia, while many others were catheterized with the use of sedation alone. The youngest child to undergo catheterization was six weeks old, while the mean age was 4.7 years. The smallest child weighed 7 pounds (about 3.2 kg.). The oldest child requiring anesthesia was thirteen years of age, although most children more than nine years of age were catheterized under sedation alone. The diagnoses varied widely; almost all of the major circulatory anomalies are included in the series (table 1). Ten of the children were digitalized prior to anesthesia, and in 1 case there developed during the procedure supraventricular tachycardia, which responded to digitalis. Only one catheterization was unsuccessful—because of inability to manipulate the catheter into the heart.

Of the 104 children receiving anesthesia, 20 received rectally administered tribromoethanol solution alone plus premedication. Fourteen of the 20 received 100 mg. per kilogram of body weight, 5 received 90 mg. per kilogram and 1 received 80 mg. per kilogram. Of the 5 children receiving 90 mg. per kilogram, 3 required additional tribromoethanol solution. Only 1 child of the 14 receiving 100 mg. per kilogram required additional tribromoethanol solution. Seventy-three children received tribromoethanol solution plus supplementary intravenously administered thiopental sodium (average dose 6.5 cc. of 1.25 per cent solution). Less thiopental sodium was needed in children

TABLE 2

DISTRIBUTION OF CASES BY TYPE OF ANESTHESIA AND DOSAGE OF TRIBROMOETHANOL SOLUTION

| Type of Anesthesia | Dosage of Tribromoethanol Solution | Cases |
|---|---|---|
| Rectal tribromoethanol solution | 100 mg./kg. | 14 |
| | 90 mg./kg. | 5 |
| | 80 mg./kg. | 1 |
| Rectal tribromoethanol solution plus intravenous thiopental sodium | 100 mg./kg. | 49 |
| | 90 mg./kg. | 15 |
| | 80 mg./kg. | 7 |
| | 70 mg./kg. | 2 |
| Rectal thiopental sodium | 15 mg./lb. | 1 |
| Rectal thiopental sodium plus intravenous thiopental sodium | 20 mg./lb. | 9 |
| Rectal tribromoethanol solution plus nitrous-oxide-oxygen | | 1 |
| Total | | 104 |

receiving the 100 mg. per kilogram dose of tribromoethanol solution than in those who received a smaller initial dose.

Only 1 child, early in the series, received tribromoethanol solution plus nitrous-oxide-oxygen anesthesia. Nine patients received rectally administered thiopental sodium (20 mg. per pound of body weight) plus supplemental intravenously administered thiopental sodium, while 1 patient received rectally administered thiopental sodium alone (table 2).

Seventeen children in the younger age group received no premedication; 9 children, also in the younger age group, received atropine sulfate alone (doses ranging from 1/600 to 1/150 gr. [from about 0.00011 to about 0.00043 Gm.]). Twenty-eight children received morphine sulfate (about 0.25 mg. per pound of body weight), together with atropine sulfate and a barbiturate; 16 children received codeine sulfate (dose range: 0.3 to 0.6 mg. per pound) combined with a barbiturate (dose range: 0.5 to 1.2 mg. per pound) and atropine sulfate. One child received meperidine hydrochloride (Demerol® hydrochloride) (0.5 mg. per pound) in combination with atropine sulfate and a barbiturate, and 18 children received a barbiturate (0.5 to 1.2 mg. per pound) and atropine sulfate (1/600 to 1/150 gr. [about 0.00011 to about 0.00043 Gm.]) (table 3).

Of the 104 children anesthetized, 52 (50 per cent) showed some degree of cyanosis prior to induction of anesthesia. The minimal arterial oxygen saturation obtained during catheterization in the cyanotic children ranged from 8 to 93 per cent. Blood samples were withdrawn within a short time from the inferior and the superior vena cava in 77 of the patients. Of these, 65 (84.4 per cent) demonstrated significantly higher oxygen saturations in the superior than in the inferior caval blood. This is contrary to the usual finding in subjects not under anesthesia (9). A similar reversal of the relative oxygen content of the inferior and the superior caval blood between the unanesthetized and the anesthetized states also has been demonstrated in dogs (10).

TABLE 3

DISTRIBUTION OF CASES BY TYPE OF PREMEDICATION

| Type of Premedication | Cases |
|---|---|
| No premedication | 17 |
| Atropine sulfate only | 9 |
| Morphine sulfate, atropine sulfate and barbiturate | 28 |
| Codeine sulfate, atropine sulfate and barbiturate | 16 |
| Meperidine hydrochloride, atropine sulfate and barbiturate | 1 |
| Atropine sulfate and barbiturate | 18 |
| Not recorded | 15 |
| Total | 104 |

Laryngospasm was observed in 2 cases, and in one of these intubation was necessitated. In 2 children, both less than 1 year of age, respiratory arrest developed when the initial supplementary small intravenous doses (1 cc., 1.25 per cent) of thiopental sodium were given. These 2 children were intubated and respirations were assisted for fifteen to twenty minutes using 100 per cent oxygen until spontaneous respirations were resumed. One child was inadvertently given an overdose of morphine sulfate premedication and experienced moderately severe nausea and vomiting. No additional analgesia was needed in this case. In 1 case, paroxysmal tachycardia developed, as previously mentioned, which responded to intravenously administered lanatoside C (Cedilanid®). No other anesthetic complications were observed and no patient, including those above, had any noticeable sequela attributable either to the anesthesia or to the cardiac catheterization.

## COMMENT

One hundred four children were anesthetied by various techniques and underwent diagnostic cardiac catheterization with no resultant deaths. Considering the increased risk in this group of patients, all with serious heart disease and some critically ill, the authors are of the opinion that the absence of mortality is due to more than chance alone. Observance of a proper precatheterization medical regimen, so that the child is brought to catheterization in the best possible status, has helped to decrease the incidence of morbidity to 5.8 per cent. The precatheterization preparation is a most important factor. Those patients receiving proper premedication tolerated the procedure best of all and yielded the most valuable catheterization data. Those patients whose anesthesia wore off within two hours and who required the greatest dose of supplemental anesthesia squirmed about as the result of minor stimuli and consequently hindered a perfect catheterization procedure. The use of adequate premedication, of rectally administered tribromoethanol solution and of supplementary small doses of dilute thiopental sodium intravenously administered as the effect of the tribromoethanol solution wears off has proved to be the most successful technique, in the authors' experience.

We have observed that many of the patients who were cyanotic prior to anesthesia showed a definite increase in arterial oxygen saturation when anesthetized. This could be compatible with a decrease in metabolism with a subsequent decrease in oxygen demand following preliminary premedication with opiates and during anesthesia. The finding of higher oxygen saturations in the superior as compared with the inferior caval blood lends support to the hypothesis that the oxygen utilization of the brain is decreased during anesthesia (11, 12). In those children catheterized while awake, the inferior vena caval blood was more highly saturated than the superior caval blood.

Many patients exhibited definite temporary decreases in arterial oxygen saturation of 4 to 5 per cent immediately after each supplemental intravenous injection of thiopental sodium, presumably as a result of the depressant effect on respiration. It is important to wait for restabilization of the oxygen saturation following this procedure in order to avoid erroneous results based on blood samples withdrawn during this period of temporary decrease.

The prophylactic use of oxygen and penicillin probably has aided in reducing the postcatheterization morbidity. Blood pressure, pulse, respirations and temperature are checked frequently in the postcatheterization period. In many of the cases, fever developed for a period of 24 hours following the procedure, but temperatures were normal after that time. This has been observed by one of us (Lundy) in many patients anesthetized with thiopental sodium for general surgery. If left undisturbed, most of the children remained asleep for many hours following the procedure. This probably is beneficial, and no attempt was made to stimulate them and to hasten their awakening.

On the basis of this experience, it is concluded that an adequate medical regimen, suitable premedication and constant vigilance during anesthesia and the postanesthetic period permit these poor-risk patients to undergo the stress of cardiac catheterization with relative safety and with few anesthetic or postanesthetic complications.

## SUMMARY

The authors' methods of inducing and maintaining anesthesia in 104 children undergoing diagnostic cardiac catheterization have been presented.

No deaths occurred and the incidence of morbidity was low (5.8 per cent). No untoward sequelae were observed following the procedure.

The value of precatheterization medical preparation and preanesthetic medication is discussed, and the importance of viligant post-procedure care is emphasized. In the authors' experience, the use of adequate premedication, followed by rectal administration of tribromoethanol solution and supplementary small intravenous doses of thiopental sodium, when required, has been satisfactory.

The oxygen content of the superior caval blood of anesthetized children usually exceeds that of blood from the inferior vena cava. The reverse is usually the case in unanesthetized human beings.

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