GENERAL ANESTHESIA FOR CARDIAC CATHETERIZATION

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Right heart catheterization is now an established, low-risk diagnostic procedure for heart abnormalities.[1, 2, 3] The technique is usually painless, but requires understanding and cooperation by the patient. This can be obtained readily in most adults and older children with whom rapport has been established. However, children under six years of age, and a few older children and adults cannot comprehend and frequently fear such a diagnostic study. In a darkened room with this type of patient the technical problems of completing a catheterization are increased. The production of a passive state with many of the depressant drugs adds unwanted danger to the patient whose condition may be considered hazardous even under the best of circumstances.[4] To produce such a state with minimum danger, fear and discomfort to the patient as well as noninterference with the catheterization technique, we chose general anesthesia.

The inhalation agents used must be nonflammable because of the electrical apparatus (fluoroscopy) needed for cardiac catheterization. Since the procedure does not require deep anesthesia nitrous oxide seemed ideal. This drug is noted for its low toxicity and minimal alteration of physiological functions in the presence of adequate oxygenation.[5, 6] To administer an inhalation agent under the conditions presented, we believed the maintenance of an open airway with an endotracheal tube was necessary. Activity of the laryngeal reflexes required some supplementation of the nitrous oxide-oxygen anesthesia and was accomplished by the addition of (1) moderate preanesthetic medication, (2) topical anesthesia to the larynx, and (3) the intermittent addition of trichlorethylene vapor to the anesthetic mixture.

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Method

The management of 67 anesthetics administered to 63 patients undergoing cardiac catheterization was as follows:

Fluids. As the catheterizations were done in the early afternoon, the children were allowed to have a clear liquid breakfast (jello, strained fruit juice, *no* milk), then nothing by mouth for the 4–5 hours preceding anesthesia. The small infants were allowed to have their feedings up until 3 hours prior to anesthesia, the last feeding consisting of 5 per cent glucose in water in place of the usual formula.

Premedication. The patients received scopolamine 0.08 to 0.12 mg., 90 minutes prior to catheterization. Meperidine (1 mg./pound up to 50 mg.) was added in children over 2½ years of age. The narcotic dosage was decreased a total of 5–10 mg. in the more severely ill patients.

Preparation. A stethescope was taped to the precordium and, in older children, a blood pressure cuff was applied. Electrocardiograph electrodes were attached in the older children, most of whom were already familiar with this apparatus. The precordial stethescope was removed at the time of fluoroscopy.

Induction. Anesthesia induction was begun by administering nitrous oxide-oxygen (6 : 2 l./minute) with a bag and mask. Trichlorethylene vapor was then added by means of a Foregger Trilene attachment with the bubbler removed. As soon as consciousness was lost the electrocardiograph electrodes, if not already in place, were attached and the tracing monitored throughout the procedure on a cathode ray oscilloscope.

Intubation. When the depth of anesthesia was adequate for laryngoscopy, the larynx and vocal cords were sprayed with cocaine 6 per cent (lidocaine 2 per cent was substituted in a few cases). Exposure of the vocal cords was usually done with ease as trichlorethylene ap-

parently diminishes laryngeal reflexes even in light anesthesia.

A properly selected endotracheal tube was inserted and connected to a nonrebreathing valve and reservoir bag. The use of muscle relaxants to facilitate tracheal intubation was not found to be necessary except in six cases (larger children and adults).

Maintenance. Anesthesia was maintained with nitrous oxide and oxygen (5–8 l./minute total flow) with small amounts of trichlorethylene vapor added intermittently only if needed. A Beckman Model D oxygen analyzer was attached to the reservoir bag and the oxygen content of the gas mixture was measured every 3–5 minutes until the desired concentration was established and stabilized. The mixture was rechecked every 15–20 minutes thereafter. Oxygen concentration was found to be quite stable after the initial 10–15 minute period and very little, if any, adjustments were necessary. No pressure was allowed on the breathing bag during right heart pressure measurements because of the immediate hemodynamic effects.[7]

Catheterization. The procedure was started after the cut-down sites were infiltrated with 1 per cent procaine and the patient's extremities taped to the mattress to prevent slight movements which may occur during very light anesthesia. Blood removed for sampling was replaced in the smaller infants at the end of the procedure via the catheter.

Results

All anesthetics were either administered personally or supervised by one individual (G. W. N. E.). Thirteen patients were not catheterized, all due to technical difficulty (*e.g.*, inability to pass the catheter into the heart). The anesthetic management did not effect incompletion of any of the procedures. Catheterization was completed in 54 patients, 3 during the second attempt. Of these 54, 2 studies were invalid because of extremely low blood oxygen saturations and abnormal oxygen values relative to the sampling site. No procedures were cancelled because of excessive depression due to preanesthetic medication. A few procedures were postponed because of elevated temperature, upper respiratory infection or cardiac failure the morning of catheterization. There were no deaths associated with either catheterization or anesthesia.

TABLE 1

Age Distribution of Patients and Incidence of Tachypnea During General Anesthesia for Cardiac Catherization

Age (Years)	<1	1–5	5–11	>11	Total
Number of patients	21	23	15	4	63
Number of patients with tachypnea	15	6	2	0	23
Per cent of age group	71.4	26.1	13.3	0.0	36.5

The ages of the patients are shown in table 1. The youngest patient was 28 days old and weighed 7 pounds 10 ounces. Of the 4 adults included in this series, ages 17, 26, 28, and 28 years, 3 were mentally retarded and the adult of normal mentality was undergoing a left heart catheterization. The tabulation of the patients' physical status is shown in table 2. Approximately one-fourth of the patients had some degree of cyanosis associated with their heart disease.

In the first 24 cases the oxygen concentration was stabilized between 30 and 50 per cent since we believed that this would increase the safety to the patient. There was no interference with diagnostic interpretation on this basis. It has been shown that inhalation of 95 per cent oxygen lowers the pressure in the right heart and pulmonary artery.[8] This technique has been utilized to reveal the presence of, for example, an atrial septal defect or patent ductus arteriosus in which a left-to-right shunt would not appear during elevated right heart

TABLE 2

Physical Status of Patients for Catheterization During General Anesthesia

Physical Status (A.S.A.)	1	2	3	4	5	6
Number of patients	3	38	21	0	0	1

pressures. Although not established, oxygen concentrations between 30 and 50 per cent might conceivably alter the cardiac dynamics and for this reason, the remaining 43 cases were done with oxygen concentration of 22 per cent (equal to room air).

The use of trichlorethylene was of some concern to us as this drug has been reported to cause arrhythmias due to increased myocardial irritability.[9, 10, 11] It would be very difficult to determine objectively if disturbance of rate or rhythm was altered by this agent during cardiac catheterization. Certainly, arrhythmias did occur, as they do even in awake patients undergoing this procedure. This is due not only to mechanical irritation of the heart by the catheter but also to the degree of myocardial irritability associated with the patient's disease. Serious, though transient, arrhythmias (ventricular tachycardia) occurred in 5 patients in this series. Brief sinus tachycardia was noted in only 8 patients. Premature ventricular contractions and ventricular extrasystoles occurred infrequently and usually disappeared with relocation of the catheter. It was our impression that the appearance and severity of arrhythmias was not increased by the anesthetic technique.

The most significant disturbance presented by this technique was the appearance of tachypnea. This was not alarming when the respiratory rate was not excessively fast (below 40/minute). However, in 5 patients the respiratory rate became exceedingly rapid (above 100/minute), thus making it difficult for the patients to ventilate much more than their physiological dead space. Of the 63 patients, 23 (36.5 per cent) had tachypnea with an increase in rate of more than ten respirations per minute (table 1).

The rapid awakening time following termination of anesthesia was of particular advantage. All but 5 patients were returned directly to the ward. The patients, although occasionally drowsy, responded well to voice and had return of their protective reflexes. The 5 patients that we believed were insufficiently awake were sent to the recovery room. Postanesthesia nausea and vomiting were uncommon and the patients were allowed liquids as soon as desired, usually on return to the ward.

Discussion

The objections against the use of nitrous oxide anesthesia for cardiac catheterization have been that maintenance of a constant concentration of oxygen was difficult and that the gas would interfere with the blood analysis. We have found that a constant concentration of oxygen could be delivered with nitrous oxide and that periodic checks of the gas mixture with an oxygen analyzer were little trouble. The Orcutt-Waters modification of the Van Slyke-Neill manometric method takes into account the presence of nitrous oxide in the blood.[12] This required only minimal alteration of the standard technique which prolonged the procedure only slightly (approximately 3 minutes/sample) and was not troublesome. If a spectrophotometric or cuvette determination of oxygen saturation was done, no alteration of technique was necessary.

The two catheterizations from which unsatisfactory results were obtained are difficult to explain. In both cases decidedly low venous oxygen saturation was obtained. The first was a three year old female with acyanotic congenital heart disease who, after the usual premedication, had an uneventful anesthetic course. The patient was crying on induction and continued to sob for a short time after anesthesia was established. Respiration increased in rate from 36 to 42/minute and remained stable for the first hour. During the last fifteen minutes of this seventy-five minute procedure, respiration increased to 60/minute. The pulse remained between 100 to 120/minute throughout the procedure with occasional premature ventricular contractions. The oxygen concentration in the breathing bag remained at 42 per cent throughout the procedure. The pulmonary artery pressure was elevated. The venous oxygen values in addition to being below normal were lowest in the pulmonary artery, next lowest in the right ventricle and highest in the right atrium. Although we can not show that the anesthetic technique was contributory to these abnormal values neither can we rule it out.

The second case was a 26 year old mongoloid female with congenital heart disease and pulmonary hypertension who had been in congestive failure and had had episodes of

cyanosis. She had no pulsations in her lower extremities although both upper extremities were normal. Following satisfactory premedication, induction of anesthesia was smooth and there was no difficulty in maintenance. Respiration and pulse varied between 20–30 and 88–92/minute respectively during the two hour and twenty minute procedure throughout which the measured oxygen concentration in the bag was equal to that of air. The pulmonary artery pressure was very high and an elevated right ventricular diastolic pressure was indicative of failure. This patient's heart was of abnormal configuration and the site of the catheter was at times open to question. The venous oxygen saturation was extremely low (below 20 per cent in some samples) and, due to sampling difficulties, the arterial oxygen saturation was not obtained. If a faulty connection had occurred between the breathing bag and the oxygen analyzer, the measured oxygen concentration might have been that of ambient air. An undetected low oxygen concentration may then have existed in the bag. There was no evidence of hypoxia in the patient's physiological signs but such signs might have been masked by the premedicants and anesthetic agents.[13] Fault in anesthetic technique might have been the cause of the low blood oxygen values.

The problem of tachypnea has been of concern to us. Tachypnea can interfere with adequate alveolar ventilation and hypoxemia associated with rapid respiration due to trichlorethylene anesthesia has been noted.[14] Rapid respiration has been reported repeatedly with the use of trichlorethylene [10, 11, 14, 15] while weak respiratory stimulation has only recently been observed during nitrous oxide-oxygen administration.[16] Both drugs have been reported to increase the sensitivity of stretch receptors in the lungs.[17] In many of our patients preexisting pulmonary congestion was present and of those exhibiting rapid respiration, all had pulmonary hypertension to some degree. However, pulmonary hypertension was present in many patients who did not have tachypnea. We believe that trichlorethylene was the major causative factor of tachypnea in our series.

When continuous trichlorethylene was used with compressed air, tachypnea was a serious disadvantage.[18] In comparison with this technique, the use of trichlorethylene intermittently and infrequently reduced the incidence of both tachypnea and tachycardia, agreeing with observations of others.[9, 11, 14] Of 4 patients who had a repeat procedure, 2 exhibited rapid respiration both times and the remaining 2 neither time.

The age of the patient appreciably affected the incidence of tachypnea (table 1). This may be due partly to the absence of narcotics for premedication in the very young. Both factors have been noted by Dundee.[14] Respiratory rates in normal newborn infants have been reported as varying considerably (20–100/minute, resting) with an average of about 45/minute.[19] In children with congenital heart disease there is frequently an abnormality of pulmonary hemodynamics as well as generalized physical retardation. The pulmonary regulatory mechanisms in these patients may be no more refined than those of the newborn.

The use of trichlorethylene supplementation therefore is not completely satisfactory because of the tachypnea associated with its use. The minor disadvantage to the use of nitrous oxide was the monitoring of the oxygen concentration. There are diagnostic tests recently developed utilizing nitrous oxide to detect left-to-right shunts which could not be performed in the presence of nitrous oxide anesthesia.[20]

The incidence of technical failures caused by movement, crying, breath-holding, awakening patients and anxiety were eliminated. Attempts at catheterization were stopped only after two or three cutdowns had failed or the fluoroscopy time limit was reached. Venospasm was uncommon perhaps due to the use of procaine at the cut-down site.

We believe that the anesthetic state was both steady and reproducible. The rapid awakening, return of protective reflexes and resumption of nutritional intake were all desirable. This was in particular contrast to the patients receiving heavy sedation and either intravenous or rectal anesthesia for this procedure.[4, 7]

Summary

Cardiac catheterization in infants, children and adults has been facilitated by general endotracheal anesthesia using nitrous oxide-oxygen supplemented by premedicants, topical anes-

thesia of the larynx and intermittent trichlorethylene vapor.

Sixty-seven cases are reported in patients with an age range of 28 days to 29 years. There were 52 satisfactorily completed catheterizations, 13 technical failures not associated with anesthesia, and 2 completed catheterizations with invalid results. There were no deaths attributable to either catheterization or anesthesia.

The only appreciable disadvantage was the occurrence of tachypnea in 36.5 per cent of the patients, particularly in infants below one year of age and primarily due to the use of trichlorethylene.

The advantages were (1) increased safety to the patient (2) decreased technical failures (3) a steady and reproducible state and (4) rapid awakening.

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