

the presence or absence of new T-wave abnormalities. Furthermore, the presence of: 1) new ST segment changes with or without symptoms; or 2) new T-wave abnormalities in association with chest pain, impaired ventricular function, or ventricular arrhythmias should be presumed secondary to ischemia unless alternative etiologies can be established.

The authors thank Sylvia Dunn for her secretarial assistance and Scott Zeger, Ph.D., for his help in statistical analysis.

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Anesthesiology
64:402-405, 1986

Anesthesia for Infants during Radiotherapy: An Insufflation Technique

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Radiation therapy is the primary treatment for retinoblastoma, a congenital malignancy usually diagnosed and treated during the first 3 yr of life.¹ The therapy is administered over a 4- to 6-week period and divided into 16 to 24 doses determined by the age of the patient and size of the tumor. Since these patients are so young, re-

peated doses of heavy sedation or general anesthesia are required to ensure absolute immobility during irradiation. Providing anesthesia that is effective, yet allows infants and children to grow and develop normally over such a prolonged period of therapy, can be challenging.

In 1963, Harrison and Bennet² introduced an insufflation technique using a Waters' oropharyngeal airway with a sidearm to administer halothane, nitrous oxide, and oxygen to infants undergoing radiotherapy. They reported no complications and rapid recovery for six infants over a course of 100 radiotherapy sessions. Infants regained consciousness within 5 min and resumed feeding within 1 h. In 1969, Browne *et al.* introduced a slightly different insufflation technique, a T-piece circuit attached to an orotracheal airway.³ They reported no complications over a course of 50 treatments.

Recently, im ketamine has been used to sedate infants

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Key words: Anesthesia: pediatric; outpatient. Anesthesia techniques: insufflation. Anesthetics, volatile: halothane; isoflurane.

and children undergoing outpatient radiotherapy treatment.⁴⁻⁷ However, our early experience using ketamine in a 3-month-old infant was disappointing. Following the first radiotherapy session, the infant became fretful and cried for prolonged periods of time. Although this behavior dissipated during a 2-day break from treatment, it recurred after each of two subsequent administrations of ketamine. To avoid this behavior change, we sought an alternative anesthetic technique.

We report our experience with an insufflation technique using a nasopharyngeal catheter for delivering isoflurane or halothane, nitrous oxide, and oxygen to infants and young children. We have used this technique in 11 infants and one 3-yr-old child.

METHODS AND MATERIALS

Over a period of 4 yr, 12 patients ranging in age from 3 months to 3 yr required retinotherapy for retinoblastoma; we reviewed these patients' charts retrospectively. Treatment for all patients was scheduled for Monday, Tuesday, Thursday, and Friday at 0700 h. Infants younger than 6 months ($n = 3$) were allowed clear liquid feeding before 0200 h. Infants older than 6 months ($n = 8$), and the one child in our study received nothing by mouth after midnight. None of the patients was premedicated.

Each patient was placed supine on the treatment table. Anesthesia was induced by breathing either halothane or isoflurane in 70% nitrous oxide and 30% oxygen *via* a mask. The concentration of isoflurane or halothane was gradually increased until anesthetic depth was sufficient to allow us to insert an oral airway. To estimate the distance to advance a catheter, we measured the distance from the patient's nose to the tragus. A soft, single-orifice 8-10 French catheter was then inserted into the posterior pharynx through either naris and taped to the infant's chest (fig. 1). The catheter was attached directly to the gas outflow line of the anesthesia machine. Once the catheter was properly positioned, the fractional inspired O_2 concentration (FI_{O_2}) was increased to 1.0 using a fresh gas flow of 5 l/min. The inspired anesthetic concentration maintained while the patient was unattended varied from 0.7% to 2.0% during isoflurane and from 0.5% to 1.5% during halothane.

During induction of anesthesia, the heart rate of all patients was monitored with a precordial stethoscope. Additional monitoring included an ECG in the first nine patients and a Nellcor Pulse Oximeter Model N-100® in the other three patients. The patient's chest, head, and monitor were observed *via* a closed-circuit television camera that transmitted to a monitor situated outside the treatment room.

When radiation treatment was completed, all patients received oxygen by mask until spontaneous movement was noted. The therapy for each patient was completed



FIG. 1. Three-month-old infant undergoing radiotherapy during anesthesia by insufflation. The catheter is in the left naris; the oral airway is in place.

during the time allotted, and either or both parents were present during induction of and recovery from anesthesia.

RESULTS

Twelve patients aged 3 months to 3 yr had 264 radiation treatments using this technique. No postanesthetic complications were evident in any of the patients. In particular, the 3-month-old patient initially given ketamine had no further episodes of unusually fretful behavior or persistent crying. All patients continued to grow and develop normally during the period of radiotherapy. One treatment session (for an 11-month-old infant) was interrupted when the oxygen saturation decreased to 92%. When the patient's airway was repositioned, the oxygen saturation increased promptly, and treatment was resumed. No further complications occurred for this infant.

Another patient (3 months of age) became apneic during induction of anesthesia for her final treatment. When we reduced the concentration of halothane and ventilated with oxygen by mask for 1-2 min, spontaneous ventilation resumed. This infant subsequently tolerated general anesthesia for outpatient eye examinations with no complications.

A third patient (6 months of age) developed laryngospasm during induction of anesthesia with isoflurane. This was treated by positive-pressure ventilation with oxygen by mask. Therapy was resumed with no further problems encountered.

The first patient in this series was transported to the recovery room. Because recovery was uncomplicated and completed within 5 min of arrival in the recovery room, the other 11 patients were observed in the radiation therapy suite until awake.

All patients were alert and discharged within 15-20 min following therapy. The younger patients (less than 6 months, $n = 3$) had tolerated a feeding, and the older infants and one child were ambulatory before discharge.

DISCUSSION

Radiotherapy for infants and young children poses several challenges. First, patients must remain absolutely motionless, but only for periods of 45–90 s. Second, patients must remain unattended during treatment to protect medical personnel from exposure to radiation. Third, there must be immediate access to the patient in an emergency. In addition, the radiotherapist must be able to obtain intratreatment roentgenograms to evaluate the precision of the targeted radiation.

To meet these requirements, we advocate anesthesia with the following caveats. First, anesthesia must be profound but of short duration. Second, remote monitoring of the ventilation and circulation must be provided. Third, postanesthesia sedation must be minimal to avoid disrupting feeding and sleeping schedules, so that infants may continue to grow and develop normally during the therapy period.

A wide range of techniques using a variety of agents has been used for this purpose. Intramuscular administration of ketamine was introduced to achieve the appropriate level of sedation more predictably and more rapidly than that achieved using sedatives such as chloral hydrate or diazepam. However, the chronic use of ketamine often produces tachyphylaxis,^{2,4,5,8,§} necessitating dose adjustments. In addition, ketamine may produce writhing body movements^{5,7,12,§} and nystagmus,⁴ both of which interfere with directing radiation to the small field of a retinoblastoma. Ketamine also produces oral secretions that can be so profuse that many experts recommend simultaneous administration of an antisialagogue^{5,9} to minimize the risk of airway obstruction^{6,12} or laryngospasm.⁷

The period of sedation that results from ketamine is variable.^{7,9} Although the high incidence of dysphoric dreaming experienced by older children and adults is much less of a problem in the age group under discussion,^{9,12,§} our 3-month-old patient exhibited unusual behavior after each of the first three therapy sessions using ketamine sedation. Once general inhalation anesthesia was substituted, the patient's behavior following treatment returned to normal.

Thiopental or methohexital administered rectally have also been used to sedate infants requiring radiotherapy. However, as with ketamine, tachyphylaxis is common when these drugs are repeatedly administered.[§] The incidence of prolonged sedation is unpredictable. Proctitis commonly accompanies repeated rectal doses of these drugs.^{2,10,§}

The effective use of the insufflation technique described in this report relies on the meticulous placement of the

nasopharyngeal catheter. The catheter must be carefully positioned to avoid entering the esophagus, which might cause gastric distension. Ideally, the oral airway functions as a valve ("pop-off") for the gases insufflated into the nasopharynx, allowing gas to enter the trachea and partially exit the mouth, instead of entering the esophagus. The use of the catheter also permits the continual delivery of a low dose of anesthetic in oxygen during the period when the patient is unattended.

Delivering the inhaled anesthetic *via* the nasal catheter rather than the oral airway previously described^{2,3} has advantages. The catheter is lightweight and easily attached to the gas outflow line of the anesthesia machine with a plastic tubing connection (Pharmseal®), which allows approximately 20–30 inches between a patient's airway and the gas outflow line (fig. 1). This avoids applying torque or tension to the side of the oral airway. This 20–30 inches proved particularly advantageous when roentgenograms were needed. We noted no complications (*i.e.*, bleeding, infection, or nasal obstruction) from using the catheter.

For these brief radiotherapy treatments (45–90 s), infants and young children require no analgesia, and consequently, low-dose isoflurane or halothane is effective. As a result, the patients' feeding habits and family routines were minimally disrupted, and nutrition and growth levels were well maintained.

In the setting of outpatient radiotherapy for infants and young children, it is tempting to believe that sedation is safer than general anesthesia. However, administering general anesthesia by insufflation provides immobility for a predictable period of time and avoids maintenance of a long-term heparin lock,¹¹ trauma of repeated needle sticks, and possible complications of repeated tracheal intubation. In addition, tracheal intubation requires a greater depth of anesthesia than our technique.

Despite the advantages of the technique we describe, there are certain situations when it is probably contraindicated. First, patients with an abnormal upper airway (*e.g.*, micrognathia) are likely to have airway obstruction during general anesthesia, and the nasopharyngeal catheter may not provide enough airway support to treat such obstruction. Second, patients with a "full stomach" may be at increased risk for aspiration if gas is insufflated into the esophagus. In addition, it is likely that waste anesthetic gases will enter the room because there is no practical way to scavenge.

We now monitor these patients with a pulse oximeter. Other clinicians have suggested monitoring chest excursion or airflow during these procedures,^{13,14} but the monitors required may not detect partial airway obstruction or a slight decrease in arterial saturation. The pulse oximeter is a noninvasive monitor that rapidly reflects a decrease in oxygen saturation,¹⁵ providing an early warning that airway patency may be compromised. Therefore, the

§ Fabian L: The experts opine. *Survey of Anesthesiology* 24:121–126, 1980.

pulse oximeter is superior to other monitors when remote observation is necessary, especially when monitoring nonintubated patients.

In summary, administering general anesthesia by insufflation provides safe and effective sedation for infants and young children who required four to five radiotherapy treatments per week for 4 to 6 weeks. The success of this method relies on the continuity of care provided by both the radiotherapist and anesthesiologist whose efforts contributed to the rapport developed with the patients' families over the course of treatment.

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Erratum

In the article "The Use of a Platelet Nucleotide Assay as a Possible Diagnostic Test for Malignant Hyperthermia," by M. B. Lee, M. G. Adragna, and L. Edwards, (*ANESTHESIOLOGY* 63:311-315), table 2 contains two incorrect numbers. Under the heading PCA, 54 should read 25, and under the heading PCA + KOH, 68 should read 50.