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Conscious sedation and pulse oximetry: false alarms?

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Abstract

The use of pulse oximetry in dental procedures involving sedation and children has been encouraged strongly. Reports have indicated that hemoglobin desaturations are not uncommon when a variety of drugs (including nitrous oxide) and dosages are used. The present study investigated the nature of desaturations in relation to patient activity as a function of a drug combination, single drug dose-response design, and placebo conditions. Twenty-two patients (mean age 29.45 months; range 20–37 months) participated in this two-part study. In part 1, 12 patients received a placebo and a combination of chloral hydrate and hydroxyzine in a crossover, double-blind design. In part 2, 10 patients received a placebo and three doses of chloral hydrate in a double-blind, randomized sequence of four visits involving a dose-response design. During each restorative visit, the peripheral oxygen saturation, expired carbon dioxide, heart and respiratory rates, blood pressure, and frontalis electromyogram of each child was monitored. The overall results of 63 visits indicated that 87–90% of the 235 desaturation episodes were due to patient movement. The clinical implications of the findings are discussed.

Introduction

Pulse oximetry (PO) is a popular and recommended electronic method of monitoring children sedated during dental treatment (Anderson 1987; Anderson and Vann 1988; Wilson and McTigue 1989). Pulse oximetry was introduced into the United States in 1981 (Anderson et al. 1988), and shortly thereafter Mueller et al. (1985) were the first investigators to study pulse oximetry in dental sedations involving children.

The theory of PO has been known for almost 50 years (Cohen et al. 1988). In principle, PO functions by detecting the relative difference in the absorption of light (red and ultrared spectrum) of saturated and desaturated hemoglobin during arterial pulsation (Alexander et al. 1989). There is recent evidence that PO does not monitor relative saturation in arterial beds, but derives its information from venous beds (Kim et al. 1986). This finding may have inferences of clinical significance and impart a reassessment of the function of pulse oximetry.

Since its introduction as a monitor during sedations involving children, there have been a few scientific reports concerning PO's effectiveness in detecting episodes of hypoxemia, despite a lack of noticeably significant changes in other vital or clinical signs during the episode (Mueller et al. 1985; Cote et al. 1988; Currie et al. 1988; Whitehead et al. 1988; Iwasaki et al. 1989). Since these studies used the indirect technique of PO as a means of determining desaturated hemoglobin, one might ask if the reported hypoxemia truly was detected on a consistent basis, or if there were other factors present that might influence the interpretation of the findings. In other words, there may be factors that could confuse true signals — a real episode of desaturation — with noise or false episodes. False episodes may be due to one of several factors including:

1. Patient movement
2. Relative hypothermia
3. Ambient light
4. Abnormal hemoglobinemias
5. Physiologic factors peculiar to regional vascular beds.

False desaturation episodes may be more frequent in the child dental patient who may be more likely to move than the adult.

Wilson et al. (1989), in a preliminary report, indicated that approximately 90% of detected desaturations in children were due to patient movement during sedative trials. The unexpected number of desaturations found were relatively large (89) with respect to the dose of premedication administered (40 mg/kg chloral hydrate and 2 mg/kg hydroxyzine) to 10 patients. This relationship between desaturations and patient movement was determined by constant monitoring by an observer who assessed the patient's status independent of the operator. Other indirect evidence suggesting false episodes of

desaturation is found in a study by White et al. (1989). They studied desaturations as a function of different drug regimens in adults. Interestingly, they found a large number of desaturations when lidocaine alone was administered.

The purpose of this two-part study was to determine the relationship between desaturations detected by PO and patient movement during sedation trials involving chloral hydrate alone and chloral hydrate with hydroxyzine.

Method

A total of 22 patients participated in this institutionally approved study. All patients were healthy (ASA I), did not take any medications for any condition, and were not allergic to any medications. They were recruited into the study following a routine dental examination during which they exhibited uncooperative behavior. The behavior consistently, but to a varying degree, involved crying, repeated attempts to escape from the dental chair or personnel, lack of compliance to commands by the dentist, and interfering hand and body movements.

In part 1 of the study, 12 patients (mean age 28.8 ± 4.3 months; range 20 to 37 months) were involved in a double-blind cross-over design involving two appointments per child (24 total appointments). These children had a minimum of four teeth that needed restorations or extractions. A placebo was administered during one appointment and a combination of chloral hydrate (40 mg/kg) and hydroxyzine (Vistaril® — 2 mg/kg) during the other appointment. The volume of the placebo and drug mixtures was adjusted to an equal volume (15 cc) and administered orally by cup or syringed slowly into the buccal vestibule, depending on patient receptiveness. The sequence of placebo-drug appointments was selected randomly for each patient. The same operator (a second-year pediatric dentistry resident) was used in this part of the study. All children were NPO from midnight before the morning of each appointment. The appointments began at 7:00 or 10:30 AM and usually were completed within two hours. The time of the appointment was constant for any given child.

Part 2 of the study involved 10 patients (mean age 30.1 ± 3.9 months; range 25 to 36 months) in a double-blind, repeated measures, dose-response design using chloral hydrate. These children required a minimum of three quadrants of teeth that needed restoration or extractions. Each child had either three (one child) or four appointments (nine children) for a total of 39 appointments. For the child who required three appointments, chloral hydrate was administered in one of three dosages (25, 50, 70 mg/kg) at each appointment. The rest of the children who required four appointments received chloral hydrate and a placebo with the dosage (25, 50, 70 mg/kg) of chloral hydrate and placebo sequentially, varying across appointments for each child. The sequence of drug-placebo visits was determined randomly for each patient. The author was the sole operator in this portion of the study, and again the children were NPO from midnight before the morning of each appointment. All appointments began at 7:00 AM and usually were completed within two hours. The placebo in both portions of the study was Tang™ which also was used to flavor the drug(s).

Usually, one week separated each visit for every child in this study. The following procedure occurred at each appointment for both portions of the study. The medical history was reviewed for changes. The child was weighed and taken with the parent to the dental operatory. Attempts were made to obtain baseline information for blood pressure (Dinamap™, Model 1846-SX—Critikon, Inc., Tampa, FL), heart rate and peripheral oxygen saturation (Nellcor® pulse oximeter and printer, Model N-100 and N-9000—Nellcor, Hayward, CA, respectively), expired carbon dioxide concentration (Datex™ CO_2 Monitor, Model 223) and integrated frontalis electromyogram or EMG (Datex™ Anesthesia and Brain Monitor, ABM-II—Datex Instrumentation, Helsinki, Finland, manufactured for Puritan-Bennett Corporation, Wilmington, MA). The appropriate size (pediatric) inflatable blood pressure cuff always was placed on the right arm. The oxygen saturation electrode was affixed to the right middle toe, and a small inverted thimble-like port was placed into the right nares for detection of expired CO_2. The five EMG leads were placed according to manufacturer's instructions, with three across the middle portion of the forehead and one each on the mastoid prominence behind each ear.

The child then was administered either the placebo or the drug(s) and taken with the parent to a waiting area. The child remained with the parent in the waiting area for 45 min and was monitored periodically by dental personnel. The child then was separated from the parent and returned to the dental operatory where all of the monitors were reattached to the child. Those children in part 1 of the study were not restrained initially, unless their activity caused total interference with the operative procedures. Children in part 2 of the study were restrained in a Papoose Board® (Olympic Medical Group, Seattle, WA). The operator administered topical and local anesthesia (usually not exceeding 1 carpule) and in most instances placed a rubber dam. The teeth either were restored or extracted. From the time topical anesthesia was administered until the completion of the operatory/extraction visit, an observer continually monitored both the patient's foot and toe movements and the oxygen saturation printout. Whenever a desatu-

ration occurred, the observer marked the printout as either no movement or movement associated. It should be noted that a desaturation was defined as any recording below 95% oxygen saturation (Mueller et al. 1985; Whitehead et al. 1989). When the operative phase was completed, the monitors were detached and the child was returned to the parents. Once the child was stable and oriented, he was released with appropriate postoperative instructions.

Results

Since the purpose of this report was to evaluate desaturations as a function of patient activity which in itself has important significance, the other physiologic data will not be reported here. The physiologic data for part 1 of the study is the subject of another report (Wilson et al. 1990). Part 2 also will be summarized in a separate report because of the difference in design and intent of the studies.

For all 63 appointments (parts 1 and 2 combined), there were a total of 235 desaturations, or an average (albeit potentially misleading) of 3.7 desaturations per visit. The range of desaturations when all patients and conditions were pooled was 0–21.

In part 1, there were 92 total desaturations in 24 visits. Of these, 80 (87%) were movement-associated, and 12 (13%) appeared to be real. In part 2 of the study, there were a total of 143 desaturations in 39 visits, with 129 (90%) being movement-associated and 14 (10%) apparently real. The distribution of real and movement desaturations as a function of sex and drug(s) or placebo visits can be seen in Table 1.

There were no significant differences in the total number of desaturations, real desaturations, or movement-associated desaturations for the variables of sex, placebo versus medication, or dosages of chloral hydrate. Also, there were no significant differences between parts 1 and 2 of the study in terms of the ages of the children.

TABLE 1. Number of Real and Movement-Associated Desaturations in Part 1 and 2

Part 1	*Real*	*Movement*
Sex		
Female	9	55
Male	3	25
Placebo	5	41
Chloral hydrate – Vistaril®	7	39
Part 2	*Real*	*Movement*
Sex		
Female	2	57
Male	12	90
Placebo	2	51
25 mg/kg Chloral hydrate	1	20
50 mg/kg Chloral hydrate	7	46
75 mg/kg Chloral hydrate	4	30

Discussion

The primary finding of this study was that the overwhelming majority of peripheral oxygen desaturations as measured by a pulse oximeter was due to patient-related movements. This finding is highlighted by the fact that variables such as sex, a placebo versus a medication visit, or different dosages of a given medication were not statistically significant factors during either true or movement-associated desaturations. These findings have significant clinical implications in the proper use of PO, its relative emphasis on other monitors, and, in particular, the awareness on the practitioner's part of the factors influencing pulse oximetry during sedations. Also, they raise questions about the results of past studies and the directions for future research in determining factors that influence desaturations.

For the practitioner, the depth of sedation should be a strong factor in determining the degree of vigilance by the operator of the patient's physiologic status. In a situation of true conscious sedation wherein the child is awake and responding appropriately to stimuli that may be of minimal intensity, an alarm of a pulse oximeter set to signal desaturations less than 95% may not invoke significant concern on the part of the practitioner; however, if the child is more deeply sedated (viz., eyes closed, does not respond to a simple command such as "open your mouth" without an accompanying nudge from the dentist), the sound of the alarm may have significant physiologic implications for the child and certainly should invoke immediate concern on the part of the practitioner.

Nonetheless, one has to be aware of distracting factors that may be responsible for sounding the alarm (Kim et al. 1986; Alexander et al. 1989). These may include the following:

1. A true desaturation
2. Small movement of the limbs or toes/fingers possibly undetected by the clinician
3. Relative hypothermia
4. Interference from ambient light sources
5. Abnormal hemoglobinemias
6. Changes in the blood flow in regional vascular beds (this may be significant if further evidence supports the notion that PO monitors venous rather than arterial saturation).

These distracting factors may be found in future studies to be even more significant in the child patient.

In this study, it is possible that the pulse oximeter was overly sensitive to patient movement or other artifact (eg.: ambient light sources). Others have indicated that

oximetry monitors vary in their ability to sense true desaturations (Anderson et al. 1988). The reliability of the monitor used in this study does not seem to be a significant issue, because the monitor has been used without desaturation incidents in similar studies on volunteer adults who were exposed to various concentrations of nitrous oxide/oxygen.

There was a trend for an increased number of real desaturations to occur as the concentration of chloral hydrate was increased. Also, there was a trend for increased movement-associated desaturations during placebo visits. This trend might be expected logically. It is impossible to know exactly what the "real desaturations" in this study represent without concomitant blood analysis.

Although not routinely observed, the placement of the rubber dam occasionally caused a real desaturation. During these instances, the capnograph (expired CO_2) readings were altered and the degree of relaxation (as determined by the frontalis EMG) was maximal, which gives the impression that the child was in a deep state of sedation than the defined state of *conscious sedation.* Correction of the airway alleviated the potentially troublesome condition. This emphasizes the fact that multiple monitors allow for increased information for the dentist and, ultimately, increased safety for the child.

Another consideration is that restraint did not seem to influence the detection of desaturations. The general trend of desaturations for placebo and medication visits overall was similar, even though in part 1 patients were not restrained (with one exception). Tight restraint may be found to influence blood flow into vascular beds and alter an otherwise normal pulsatile flow to the distally oriented vascular beds being monitored. This issue needs further evaluation.

There is no doubt that PO is an important and recommended aspect of proper patient monitoring during sedations. As indicated above, the deeper the level of sedation, the greater the relative importance of the monitor's function. In fact, the pulse oximeter probably is significantly more relevant during general anesthesia than during a true conscious sedation session, since the direct responsibility for the patient's well-being has shifted from the patient to the practitioner. Nonetheless, a clinically relevant indicator of patient consciousness and its relationship to physiologic mechanisms associated with airway control has not yet been identified. Therefore, it becomes imperative that the monitor be used as a regular adjunct to clinical monitoring, in case the patient looses airway control.

The exact relationship between the degree of desaturations detected by pulse oximetry and correction of the airway either by the patient or practitioner remains to be determined. Several studies (including this one) reported that correction of the airway resulted in elimination of desaturations (Mueller et al. 1985; Whitehead et al. 1988; Iwasaki et al. 1989). The question arises, however, as to whether or not the desaturation would have returned rapidly to a fully saturated state if no intervention was taken by the operators and no other monitors (especially a capnogram) indicated patient distress. Certainly, desaturations due to movement did return to a reading of full saturation immediately following the movement. It is apparent to us that future studies should discriminate between movement or procedural desaturations and those that are real.

Future studies should explore the implications for pulse oximetry when nitrous oxide is used in conjunction with other sedatives. Other studies also should investigate whether the increased oxygen partial pressure can affect the number of desaturations that will occur during sedative sessions. Future well-controlled studies on pulse oximetry and other monitors should be conducted to aid the practitioner in maintaining the safety of patients during sedation.

The procedures, possible discomforts or risks, as well as possible benefits, were explained fully to the human subjects involved, and their informed consent was obtained prior to the investigation.

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Oral complications of cancer therapy

The oral cavity is frequently a common site of complications resulting from cancer therapies.

At a National Institutes of Health (NIH) conference held in April, discussions focused on the most effective means of limiting oral complications by pretherapy interventions, as well as strategies for the management of acute and chronic complications arising during cancer therapy.

The consensus development panel, consisting of representatives from medicine, dentistry, and nursing, evaluated scientific evidence presented by experts in the management of cancer patients.

Pretherapy intervention

There is evidence that pre-existing oral pathoses unrelated to cancer or therapy may increase the risk of oral complications. Therefore, a comprehensive pretreatment dental evaluation should be performed before the initiation of cancer therapy.

Pretreatment strategies include evaluation, treatment of pre-existing dental disease, prevention of oral mucosal infections, interventions to modify salivary gland dysfunction, and prevention of mucositis, among others.

During cancer therapy

Oral complications occurring during treatment include mucosal inflammation and ulceration, oral candidiasis, bacterial and viral infections, and mucosal bleeding.

There is currently no single agent completely effective in preventing therapy-related mucositis. Patients at risk for oral herpes simplex virus may benefit from the use of either oral or intravenous acyclovir. Topical forms of therapy for oral candidiasis include nystatin and clotrimazole.

Severe thrombocytopenia may predispose patients to bleeding from routine mechanical oral hygiene procedures. In these patients, dental plaque can be managed effectively by daily mouth rinsing with a chlorhexidine solution.

Following cancer therapy

Management of chronic xerostomia involves a combination of strategies, including continuous maintenance of effective oral hygiene to reduce the proliferation of oral pathogens, use of water or artificial saliva to keep the mouth moist, and stimulation of residual salivary parenchyma to produce more saliva.

In the event that dental extraction is required following radiation, meticulous surgical technique and antibiotic prophylaxis are necessary.

Directions for the future

Emphasis must be placed on devising accurate, quantifiable and reproducible criteria for assessing the oral complications of cancer therapy, as well as establishing large-scale databases to determine incidence, prevalence, and risk factors for oral complications.

The panel felt that the therapeutic team should be multidisciplinary and sensitive to patients' emotional and physical needs. Through coordination of committed members of the dental, medical, and nursing professions, many research goals can be reached.