Monitoring pediatric dental patients with nasal mask capnography

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Abstract

Purpose: *The purpose of this study was to evaluate the potential of using capnography to analyze respiratory samples taken from a scavenging nitrous oxide nasal hood during routine pediatric dental procedures.*

Methods: *Twenty-two subjects, aged 60-116 months, were administered alternately either 40% nitrous oxide/60% oxygen or 100% oxygen during two sequential restorative appointments. All subjects were monitored continuously for end-tidal carbon dioxide and respiratory rate using a capnograph whose sampling line was attached directly to the nitrous oxide nasal hood. The subject's breath sound, displayed behavior, type of dental procedure being performed, and presence of rubber dam isolation were recorded every minute throughout the two appointments.*

Results: *Values for end-tidal carbon dioxide and respiratory rate were displayed on the capnograph when administering either oxygen or a combination of nitrous oxide/oxygen inhalation through the nasal hood. These respiratory values were lowered significantly when comparing 40% nitrous oxygen-60% oxygen to 100% oxygen inhalation. They were not significantly altered by the type of breath sound, patient behavior, dental procedure, or presence of rubber dam isolation, with the exception of some dental procedures which significantly lowered end-tidal carbon dioxide. The apnea alarm on the capnograph occurred during 5% of the total treatment time, but its occurrence represented a 97% false positive rate. The occurrence of the apnea alarm was significantly associated with the type for breath sound, patient behavior, and dental procedure. When used in this manner, the capnograph was effective in alerting the practitioner to potential apneic events, but likely has limited value in monitoring valid end-tidal carbon dioxide levels due to limitations in the sampling technique.*

Conclusions: *This study demonstrated the potential of the capnograph as a respiratory monitor for pediatric dental patients when the sampling line was attached to a scavenging nitrous oxide nasal hood. (Pediatr Dent 22:120-124, 2000)*

Several technological advances have improved the clinician's ability to monitor a sedated child's physiologic status. Pulse oximetry is advantageous in detecting developing hypoxemia by measuring decreases in percent hemoglobin oxygen saturation (SaO_2).[1] Since the occurrence of hypoxemia is related to the presence of hypoventilation, airway obstruction, or apnea, an ideal monitor should be able to detect these events directly. The capnograph is such a monitor that provides the ability to detect changes in ventilation before detectable changes occur in hemoglobin oxygen saturation, as measured by the pulse oximeter.[1-5] Capnography uses infrared spectrometry to provide an instantaneous and continuous graphic record of the carbon dioxide content in expired gases, and a digital recording of respiration rate and end-tidal carbon dioxide concentration ($PetCO_2$).[6] $PetCO_2$ is the end-expiratory carbon dioxide concentration prior to the initiation of inspiration. $PetCO_2$ closely represents $PaCO_2$ in a manner similar to SaO_2 representing PaO_2.

Previous studies have evaluated capnography using a sampling cannula inserted into the nares of non-intubated patients.[2, 7-10] These studies demonstrated that increased $PetCO_2$ during hypoventilation correlated directly with a corresponding increase in $PaCO_2$, and that, during apnea, $PetCO_2$ decreased immediately to zero. Although increases in $PetCO_2$, as measured by capnography using a nasal cannula sampling line, were not always predictive of subsequent decreases in SaO_2 during pediatric dental sedations, it was accurate in detecting complete airway obstruction or apnea.[2] Capnography was also a useful indicator of hypoventilation and underlying hypercarbia, which, by themselves, do not lead to a decrease in SaO_2, as detected by pulse oximetry.[3] Current guidelines adopted by the American Academy of Pediatric Dentistry require monitoring with capnography during deep sedation and recommend it for Level 3 conscious sedation where monitoring with pulse oximetry is required.[11]

Studies of sedated pediatric dental patients have noted some physical limitations of the nasal cannula approach to obtain respiratory samples, as the cannula prongs can become occluded by nasal mucous or mucosa due to the small diameter of the child's nares and/or can be displaced during patient movement.[3, 4] In a recent review of the clinical application of monitors employed during pediatric dental sedation, Wilson[12] regarded the use of the conventional two-pronged nasal cannula, designed for oxygen supplementation, as impractical and inefficient in sampling $PetCO_2$ in children because of the prong's dimensions. Since the disproportionally large prongs can become blocked, he recommended the fabrication of a custom-made, thimble-shaped, acrylic port inserted into one naris to which the sampling line was placed and secured to the child's face with tape. The limitations of this approach, however, were that the custom-made port required individualized

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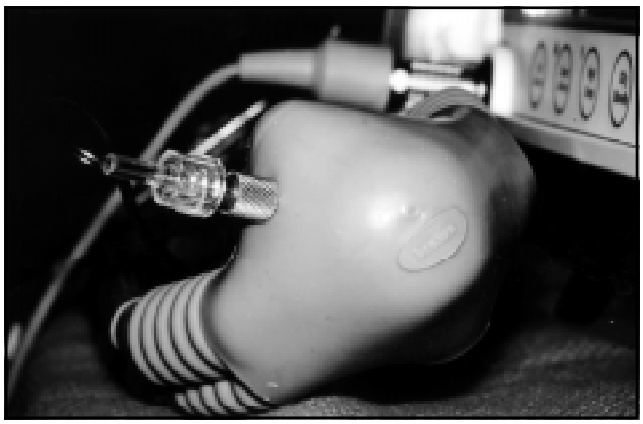

Fig 1. A sidestream carbon dioxide sampling line from a combined pulse oximeter and capnograph (POET TE Plus, Criticare System, Waukesha, WE) attached to a luer-lock adapter inserted through the side of a scavenging nitrous oxide nasal hood (Brown Scavenging Mask, Porter Instrument Co., Hatfield, PA).

fabrication and the potential for occlusion with mucous was still present.

In the present study, an innovative approach to collecting respiratory samples for capnography was evaluated in children receiving routine dental procedures. Rather than using a nasal cannula or an acrylic port, the capnograph sampling line was inserted through the side of a scavenging nitrous oxide-oxygen nasal hood. The purpose of this study was to evaluate the potential of using capnography to analyze respiratory samples taken from a scavenging nitrous oxide nasal hood during routine dental procedures.

Methods

All children in the study were recruited from the Pediatric Dental Clinic at the University of Florida College of Dentistry. Only healthy children (ASA I), not taking any medications, and without contraindications to nitrous oxide administration, were selected as subjects. The sample was collected from 22 children (10 males, 12 females), ages 5 to 9 years old, exhibiting cooperative, but anxious behavior during previous dental treatment. In the judgment of the operator, all children recruited for the study could benefit from the use of nitrous oxide-oxygen inhalation during their proposed dental treatment. Criteria for subject selection also dictated that the patients required at least two appointments of restorative dentistry with similar complexity, using rubber dam isolation, and local anesthesia. The procedures, possible discomforts or risks, as well as possible benefits, were explained fully to the subjects involved and their informed consent as approved by the University's Institutional Review Board was obtained prior to the investigation.

The subjects were randomly assigned to one of two groups. One group received 100% oxygen at the first appointment and 40% nitrous oxide/60% oxygen at the second appointment. The other group received 40% nitrous oxide/60% oxygen at the first appointment and 100% oxygen at the second appointment. The grouping of subjects was designed to evaluate the effects of nitrous oxide/oxygen inhalation on behavioral and physiological parameters, as reported in another study.[13] Nitrous oxide-oxygen inhalation was delivered by a portable nitrous oxide unit (MRX, Porter Instrument Co., Hatfield, PA) at a flow rate of 4-6 L/min. A scavenging system with a child-sized nasal hood (Brown Scavenging Mask, Porter Instrument

Table 1. Respiratory Measurements (Mean±SEM) Obtained by Nasal Mask Capnography

Group	Variable	End-Tidal CO_2	*P*-value*	Respiration rate	*P*-value*
Baseline	—-	35.96±0.86		22.05±1.05	
Nitrous oxide	100% O_2	26.93±0.23		23.25±0.28	
	40% N_2O/60% O_2	21.20±0.27	<0.001 (s)	22.27±0.31	0.018 (s)
Breath sound	Clear	24.48±0.20		22.68±0.21	
	Stridor	22.59±0.91	0.057	23.55±0.65	0.376
	Absent	0		0	
Patient behavior	Quiet	24.43±0.20		22.76±0.21	
	Crying	23.89±0.92		22.58±0.96	
	Struggling	23.50±2.74	0.766	18.62±2.73	0.314
Dental procedure	Patient Undisturbed	25.98±0.40		22.32±0.50	
	Topical Anesthesia	23.82±0.89		22.14±0.74	
	Local Anesthesia	24.45±0.58		23.35±0.60	
	Rubber Dam Placement	25.10±0.80		24.60±0.87	
	Restorative Dentistry	23.55±0.27	<0.001 (s)	22.66+0.24	0.117
Rubber dam	Present	23.98±0.29		22.79±0.27	
Isolation	Absent	24.69±0.27	0.078	22.69±0.29	0.808

*Factorial ANOVA (Fisher's PLSD).
(s) Indicates statistical significance.

Table 2. Effect of Breath Sound, Patient Behavior and Dental Procedure on the Occurrence of Apnea Alarm (per minute interval)

	Apnea alarm		
Breath sound	**No**	**Yes**	***P*-value**
Clear	1298	72(5%)•	
Stridor	65	0	
Absent	0	2	<0.0001 (s)
Patient behavior			
Quiet	1285	58 (4%)	
Crying	73	12 (14%)	
Struggling	5	4 (44%)	<0.0001 (s)
Dental procedure			
Patient undisturbed	396	10 (3%)	
Topical anesthesia	73	6 (8%)	
Local anesthesia	114	19 (14%)	
Rubber dam placement	78	3 (4%)	
Restorative dentistry	702	36 (5%)	0.0005 (s)

• False positive apnea (97.3%).
(s) Significance by chi-square analysis.

Co., Hatfield, PA) was employed at a 45 L/min evacuation rate, as recommended by NIOSH.

Prior to each trial, every subject received an airway patency assessment to verify the absence of an upper respiratory infection and to confirm that the subject was able to easily breathe through the nose. All patients were monitored continuously for end-tidal carbon dioxide and respiratory rate using a capnograph (POET TE Plus, Criticare System, Waukesha, WI) by the same observer/recorder. A sidestream carbon dioxide sampling line, using 150mL/min flow rate, was attached by a luer-lock adapter through the side and into the inner mask of the scavenging nasal hood. (Fig 1)

Baseline values were recorded for the first minute and then readings were taken subsequently at the end of each minute-long interval of treatment from the tabular trend display on the monitor. The apnea alarm on the monitor was set at a 10-second delay and each alarm incident was recorded corresponding to the one-minute interval of its occurrence. In addition, the patency of the airway was also continuously monitored using a pretracheal stethoscope, and breath sounds were recorded every minute as either clear, stridor, or absent. An apneic event was noted only when the apnea alarm was confirmed by auscultation via the pretracheal stethoscope. The response to a confirmed apneic event was to ask and/or assist the subject to reposition the head to obtain a patent airway. This maneuver was followed by continuous visual assessment, auscultation of breath sounds, and visualization of chest movement.

A simplified modification of the Ohio State University Behavior Rating Scale (OS)[14] was used by the observer/recorder to rate patient behavior using an ordinal scale that categorized behavior as either: quiet, crying, or struggling. These ratings were mutually exclusive and only one rating was selected as a global assessment of behavior displayed for each minute. The trial was terminated if compliant behavior was not obtained consistently from the patient. The dental procedure being performed was likewise recorded for every minute interval as either: patient undisturbed (no procedure occurring), topical anesthetic administration, local anesthetic administration, rubber dam placement, or restorative dentistry. The presence of rubber dam isolation was also recorded for each minute interval during the trial.

Results

Twenty-seven subjects were recruited for the study. Three patients did not complete the study due to behavioral problems interfering with the recorder's ability to collect valid data, and two subjects did not return for the second appointment. The 22 subjects completing the study had a mean age of 7.3 years (range = 60-116 months).

Table 1 demonstrates mean values for end-tidal carbon dioxide ($PetCO_2$) and respiratory rate (RR) sampled through a scavenging nasal hood during various intra-operative procedures and conditions. These respiratory values were lowered significantly when administering 40% nitrous oxide/60% oxygen compared to 100% oxygen inhalation. $PetCO_2$ and RR were not significantly altered by the type of breath sound, patient behavior, dental procedure, or presence of rubber dam isolation, with the exception of some dental procedures which significantly lowered end-tidal carbon dioxide. The specific dental procedures that significantly lowered $PetCO_2$ were topical anesthesia placement (P=0.019), local anesthesia administration (P=0.029), and performing restorative dentistry (P<0.001).

The occurrence of the apnea alarm was significantly associated with the type of breath sound, patient behavior, and the dental procedure performed (Table 2). The apnea alarm occurred during 5% of the total treatment time, but 97% of these alarms were false positives, as determined by the confirmation of clear breath sound via pretracheal stethoscope. The apnea alarm occurred with higher frequency during adverse behavior (crying and struggling) and during local anesthesia administration. During the total 1,347 minutes recorded, there were only two confirmed apneic events, as defined by the study protocol. Although recorded in two different subjects, both were females, ages 90 and 95 months, without tonsillar enlargement, who received 36 mg of lidocaine. Both displayed quiet behavior during restorative dentistry with rubber dam isolation and mouth prop placement at the time of the apneic event. The capnograph was 100% effective in determining true apneic events, as confirmed by the absence of breath sound.

Discussion

Although $PetCO_2$ measurements are obtained in a non-invasive manner with capnography, there are some inherent problems with using sidestream sampling of nasal respirations that can lead to the potential underestimation of $PetCO_2$. Underestimation of $PetCO_2$ values when using nasal samples is related to the inadequacy of the gas sample obtained due to

dilution or obstruction. Inadequate sampling when using nasal samples can also be created by mouth breathing, hyperventilation (rapid, swallow breathing >31 respirations/min), and by high sampling flow rates (>150 mL/min).[4, 15] Although nitrous oxide can interfere with the infrared analysis of carbon dioxide due to overlapping absorption spectra, this interference only occurs with nitrous oxide concentrations greater than 50%.[16, 17]

The innovative sampling approach of placing the carbon dioxide sampling line of the capnograph into the nitrous oxide nasal hood was effective in obtaining respiratory samples. Previous studies using a nasal cannula to retrieve respiratory samples reported that the cannula prongs frequently became occluded by nasal mucous or mucosa.[3] Another physical limitation of nasal cannula sampling was the difficulty encountered in administering nitrous oxide simultaneously via a nasal hood when the nasal cannula was present. By placing the sampling line through the side of the nasal hood, this problem was avoided. Nitrous oxide-oxygen inhalation was administered easily to the child patient and no incidences of an occluded sampling line occurred during the trials.

Because nasal samples were taken in an open system where dilution by oral breathing and exposure to room air occurred, the $PetCO_2$ levels recorded in this study may reflect underestimated readings. Inadequate sampling, when using only nasal expirations, can be created by mouth breathing and hyperventilation (rapid, swallow breathing >31 respirations/min), resulting in an underestimation of $PetCO_2$.[4,15] For example, crying behavior during certain dental procedures was shown to result in oral shunting of expired air and thus diluted the sample from the nasal cannula, resulting in lowered $PetCO_2$.[14] In the present study, significantly lowered $PetCO_2$ values were obtained during certain dental procedures, such as the administration of local anesthesia, where crying behavior was displayed. When using this sampling approach, erroneously low $PetCO_2$ levels also can be obtained because of the potential for sample dilution by concurrent room air sampling.[2] Although not measured, the application of scavenging at the sample site could likewise result in erroneously low $PetCO_2$ recordings.

Other than the possibility for sampling error as cited above, it is difficult to explain the significant influence of nitrous oxide inhalation on reducing $PetCO_2$ levels as reported in this study. In a recent laboratory study, the administration of 50% nitrous oxide/oxygen to midazolam-sedated rats prevented the significant increase in $PaCO_2$ measured when breathing room air only.[18] The authors of this study concluded that, when combined with sedative agents, there may be a beneficial influence of nitrous oxide and concurrent supplemental oxygen administration by reducing the occurrence hypercarbia. Because of the potential for sampling error in the present study design, the effect of nitrous oxide-oxygen inhalation on $PetCO_2$ levels is inconclusive and remains the subject for further investigation.

The more appropriate application of capnography in a pediatric dental setting would be its use as an apnea monitor.[2] Houpt and coworkers[19] described the application of apnea monitoring, but did not report on the incidence of apneic events recorded during a pediatric sedation investigation. The results of the present study showed that the capnograph was 100% effective in alerting the practitioner to confirmed apneic events. Since these pediatric dental patients were not given other sedative agents, the incidence of apnea was low as compared to the report by Rohlfing and coworkers, [20] where the overall incidence of apnea, as measured by capnography, was approximately 39%. They reported an incidence of 22 apneic events occurring over 28 appointment periods.

The incidence of false positives for the apnea alarm was high (97%) and occurred about 5% of the total treatment time. These events might be attributed to breath holding and mouth breathing, especially during local anesthesia administration, and did not represent true respiratory compromise. In a study of pediatric dental sedations with 100% oxygen supplementation and monitored by nasal cannula capnography, the false alarm rate for apnea (greater than 15 seconds duration) was 88%.[3] This high false alert rate was attributed to poor patient behavior (crying/mouth breathing) or cannula displacement. All 12% of the apneic episodes determined to be indicators of true respiratory compromise occurred during periods of sleep or quiet behavior. All episodes were secondary to airway obstruction and were corrected within 30 seconds by repositioning the patient's head. This immediate response resulted in no episodes of hypoxemia being detected by pulse oximetry. The two incidences of confirmed apnea reported in the present study occurred during restorative dental procedures under rubber dam isolation during quiet behavior. The clinical significance of the reported apnea must take into account the alarm setting at a 10-second delay interval. This is a shorter interval than the 15-20 second duration used in the cited pediatric dental sedation studies.

The results of the present study suggested that a capnograph employed with the sampling line inserted in the side of a scavenging nasal hood should be considered a valuable early warning tool to detect apnea. This innovative approach facilitates delivery of nitrous oxide/oxygen inhalation and minimizes the complications associated with the displacement and occlusion of the sampling line that occurs with the nasal cannula approach.

Conclusions

1. $PetCO_2$ and RR measurements taken from samples obtained within a scavenging nitrous oxide nasal hood were independent of any influence presented by the type of patient breath sound, patient behavior, and the presence of rubber dam isolation, but were significantly lowered by some dental procedures and the inhalation of 40% nitrous oxide when compared to 100% oxygen.
2. The occurrence of the apnea alarm displayed by the capnograph: was significantly associated with the type for breath sound, patient behavior and dental procedure; had an incidence of about 5% of the total treatment time; was determined to be a false positive event approximately 97% of the time.
3. Respiratory samples can be obtained by inserting the sampling line of the capnograph directly into the side of a scavenging nitrous oxide-oxygen nasal hood rather than by using a nasal cannula.

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Abstract of the Scientific Literature

Annual Report on Access to and Utilization of Health Care for Children

This report provides the first comprehensive data on health care of American children in more than a decade (since 1987). It is intended to be the first in an annual series and will serve as a baseline for tracking changes in health care delivery and access.

The report documents the kind of care that children receive based on categories like age, ethnicity, family employment status, and census region. It also looks at each category in terms of those children with private, public, or no insurance. Nearly 90% of children had either public or private insurance at some time during the year, though there is substantial movement of children on and off insurance. At any single point, the number of children who are uninsured rises to about 15%. Thirty four percent of infants less than 1 year old and 25 percent of children 1 to 4 receive public health insurance. A relatively large number of adolescents age 15 to 17 are uninsured (about 12%) because they rely disproportionately on private insurance.

For dental care visits, "fewer than one-half of all children and adolescents had a dental care visit in 1996 and no subgroup of children even reached 60% with at least one visit. Children 5 yrs and over were more likely than children less than 5 yrs old to have at least one dental care visit. Black (27%) and Hispanic (29%) were less likely than white children (49.2%) or children of other racial/ethnic groups (42%) to have dental care visits."

Comments: This study comes out of a 2000 issue of Pediatrics and should be quoted often in dealing with Medicaid providers. Future studies will look at more timely data and will focus on details such as expenditures and state-by-*state trends.* **LPN**

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Mc Cormick MC, Kass B, Elixhauser A, Thompson J, Simpson L: Annual report on access to and utilization of health care for children and youth in the US-1999. Pediatrics 105(Part 3 of 3 special supplement entitled Journal of the Ambulatory Pediatric Care Association):219-230, 2000.

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