

Transcutaneous oxygen monitoring of patients undergoing nitrous oxide-oxygen sedation

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Abstract

The objective of this study was to assess the changes in transcutaneous oxygen tension in pediatric patients undergoing nitrous oxide-oxygen analgesia. A total of 19 healthy patients, ranging in age from 3 to 19 years with a mean age of 9.8 years, were included. Transcutaneous oxygen monitoring was performed; following stabilization, baseline readings were obtained. Oxygen was delivered at 3 l/min for 5 min, followed at 5-min intervals by oxygen at 5 l/min, oxygen at 5 l/min with 20% nitrous oxide, oxygen at 5 l/min with 40% nitrous oxide, and finally 100% oxygen at 5 l/min.

Transcutaneous oxygen levels remained above baseline throughout the study period. There was an indication that increasing nitrous oxide concentration tended to depress somewhat the transcutaneous oxygen levels.

Transcutaneous oxygen monitoring seems to offer a reliable noninvasive continuous modality of early detection of ventilation-related complications.

The use of various sedation techniques in conjunction with dental treatment is a significant adjunct to modern dentistry. One of the most frequently employed sedation techniques is nitrous oxide-oxygen analgesia.^{1,2}

New guidelines concerning appropriate methods of monitoring sedated patients have been proposed by various dental and medical organizations.³

The relative safety of nitrous oxide-oxygen analgesia is well established. Only minimal changes occur in pulse rate, respiration, and blood pressure.^{2,4,5} The effects of nitrous oxide-oxygen analgesia on transcutaneous oxygen tension (TcPO₂) have not been studied adequately. As with other sedation techniques, proper application and reliable monitoring of patients undergoing nitrous oxide-oxygen analgesia

are essential.³ TcPO₂ monitors, due to their noninvasive nature, seem ideal for monitoring dental patients.

This study assesses the changes in TcPO₂ in pediatric dental patients undergoing nitrous oxide-oxygen analgesia.

Literature Review

Everett and Allen² evaluated the cardiorespiratory effects of nitrous oxide-oxygen inhalation with 10-40% concentration. A progressive rise of mean arterial pressure paralleled the rise of nitrous oxide concentration. A minor decrease of cardiac output was noted at all concentrations. Arterial oxygen concentration rose significantly at all concentrations of nitrous oxide-oxygen analgesia.

Trieger et al.⁴ studied the effects of nitrous oxide-oxygen inhalation on blood pressure. There was a rise of 9 mm of mercury systolic pressure, after 25% nitrous oxide was given for 2 min. There was a general trend toward a decreased rate of respiration at all levels of nitrous oxide inhaled, but this decrease was insignificant.

Roberts and Gibson⁵ evaluated the physiologic changes during nitrous oxide-oxygen analgesia in pediatric patients and reported a gradual drop in pulse rate over 50 min and a gradual return trend in 50-60 min. A decrease of 2-3 breaths/min in respiratory rate also was observed. No statistical data analysis was reported.

Surface electrodes for monitoring partial oxygen pressure have been available since 1975. TcPO₂ measurements performed with a heated Clark electrode repeatedly have shown high correlations of TcPO₂ to simultaneously measured arterial oxygen tension

(PaO²).⁶ This modality is of particular interest to dentists because it affords continuous noninvasive monitoring of oxygen tension during sedation with potential improvement in early detection of ventilation-related complications.⁶

Methods and Materials

Nineteen healthy patients ranging in age from 3 to 19 years (mean age 9.8) were selected randomly. Each child and/or parent received a brief description of the procedure prior to actual initiation of treatment. Informed and written consent was obtained prior to participation in the study.

Transcutaneous oxygen monitoring was performed utilizing a monitor^a employing a modified Clark polygraphic electrode and heat thermistor. The electrode was calibrated using zero solution and room air. The patient's skin was cleaned with alcohol and the electrode was placed on the inner aspect of the lower arm, as recommended by the manufacturer. The electrode temperature was 44°C, allowing stabilization to occur over a period ranging from 8 to 15 min. When stabilization was achieved, baseline readings were obtained. A nitrous oxide-oxygen inhalation mask was placed on the patient, and concentrations of oxygen and/or nitrous oxide-oxygen then were delivered to each patient according to a predetermined sequence. The sequence of gas delivery was as follows: 100% oxygen at 3 l/min; followed at 5-min intervals by 100% oxygen at 5 l/min; nitrous oxide at 20% with oxygen at 5 l/min; nitrous oxide at 40% with oxygen at 5 l/min; and finally, 100% oxygen at 5 l/min. Transcutaneous oxygen readings were recorded every minute throughout the study, beginning at baseline. Routine dental treatment was accomplished during the relative analgesia and recovery phases of sedation, utilizing standard techniques and maintaining a rubber dam throughout the treatment period.

Findings

Data were analyzed by means of a one-way analysis of variance (ANOVA) of repeated measures with the BMDP2 V statistical program.⁷ Overall, statistically significant differences were found ($F = 34.43$; $df = 30,540$) at the 0.0001 level. Differences between baseline and other time points were tested using the Sheffee multiple comparison method. Figure 1 represents a plot of the mean TcPO₂ values at each time point (minutes) for the 6 variants of baseline or nitrous oxide-oxygen concentrations.

The mean for the baseline reading was 95.58. By the fourth min, following the initial introduction of

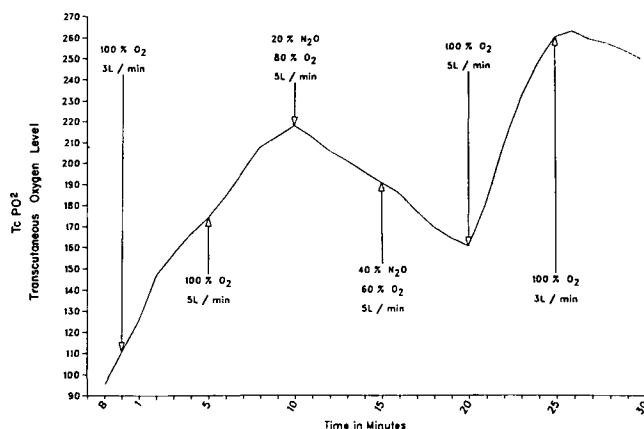


FIG 1. The transcutaneous oxygen level at baseline and throughout the observation period.

100% oxygen at 3 l/min, the mean TcPO₂ levels remained significantly higher than the baseline until the 20th min into the study, after 40% nitrous oxide had been introduced ($x = 160.00$) (Fig 1).

From the 21st min into the study, 1 min after nitrous oxide was terminated (thus delivering only 100% oxygen at 5 l/min) the TcPO₂ remained significantly above the baseline value for the duration of the study.

Also, during the 5-min interval in which 100% oxygen at 5 l/min followed the termination of nitrous oxide delivery at 40%, the increase in TcPO₂ level rose significantly from $x = 179.95$ after the first min to $x = 245.89$ after the fourth min.

At the 26th min, oxygen was withdrawn, but monitoring of TcPO₂ levels continued for an additional 4 min. Peak TcPO₂ levels were reached at the 26th min, but were followed by a gradual steady decline until the 30th min when the study was terminated.

The arrows on the graph indicate the time of shifting to a new gas or concentration.

In order to test age-related variability, the sample was divided into 3 groups: the preschool group, which ranged in age from 3 to 6 years; the school group, which ranged in age from 7 to 12 years; and, the adolescent group, which ranged in age from 17 to 19 years. ANOVA showed no significant differences among the 3 age groups for oxygen saturation.

Discussion

Transcutaneous oxygen measurement utilizing a heated Clark electrode have shown high correlations to simultaneously measured arterial oxygen tension (PaO²).⁶ Several authors have demonstrated the reliability of this system in providing continuous, non-invasive measurements of oxygen tension in children and adults.^{6,8} This modality is of particular interest to dentists who perform conscious sedation, espe-

^a Transcom 807 — Novamatrix Medical Systems: Wallingford, CT.

cially where conventional determinants of the level of awareness are not applicable, such as in pediatric dentistry. Hypoxia, due to airway impairment or secondary to respiratory depression, can be detected at an earlier stage, thus enhancing the safety of such techniques.

As demonstrated in this study, there was an obvious rapid response by the monitor to induced fluctuations of oxygen flow rate. It is of interest to note that the introduction of nitrous oxide tended to lower TcPO₂ values, despite maintaining the same oxygen level. Appropriate ventilation, patent airway, and proper oxygenation of the patient undergoing sedation with nitrous oxide and other agents should be considered carefully.

This study showed a continuous decline of TcPO₂ values as a result of introducing nitrous oxide. This decline was reversed by terminating sedation and continuing oxygenation. It is not known from this study whether the decline in TcPO₂ values would have continued and at what point they would level off.

The results of this study are in general agreement with the work of several investigators concerning the high safety associated with nitrous oxide-oxygen analgesia when used with indicated levels of oxygen.^{2,4,5}

Future research should be directed at finding reliable and efficient monitoring techniques for preschool children and also at establishing better understanding of the physiology of the respiratory system of infants and young children.

Conclusions

1. Changes in transcutaneous oxygen level (TcPO₂) corresponded positively to the rate of oxygen flow.

2. TcPO₂ dropped consistently when nitrous oxide was introduced, despite the maintenance of the same level of oxygen flow.

3. The decline in TcPO₂ levels was enhanced by increasing the percentage of nitrous oxide delivered.

4. The use of nitrous oxide-oxygen as administered in this study yielded TcPO₂ values higher than baseline throughout the study.

5. Delivering 100% oxygen and 5 l/min oxygen with 20% nitrous oxide yielded significantly higher TcPO₂ values than baseline.

6. Delivering 5 l/min oxygen with 40% nitrous oxide yielded higher TcPO₂ values than baseline; however, the difference was not statistically significant.

7. When patients were grouped according to age, no statistically significant differences existed among the 3 groups.

8. Transcutaneous oxygen monitoring seems to offer an excellent, noninvasive continuous method of early detection of ventilation-related complications.

Dr. Cassidy is in private practice in Dalton, Georgia, and at the time of this study was a senior resident in pediatric dentistry at Children's Hospital of Pittsburgh; Dr. Nazif is director and Dr. Ready is a staff member, also at Children's Hospital; and Dr. Zullo is a professor, Dept. of Learning Resources, University of Pittsburgh School of Dental Medicine. Reprint requests should be sent to: Dr. M.M. Nazif, Dental Dept., Children's Hospital of Pittsburgh, 125 DeSoto St., Pittsburgh, PA 15213.

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