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Electromyography: Its Potential as an Adjunct to Other Monitored Parameters During Conscious Sedation in Children Receiving Dental Treatment

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The purpose of this study was to evaluate the effect of a combination of a low dose of chloral hydrate and hydroxyzine on the frontalis muscle electromyogram in addition to other physiologic parameters in pediatric dental patients. A double blind, two-appointment cross-over design was used. Either a placebo or a combination of chloral hydrate and hydroxyzine was given to children during the first visit with the sequence of placebo/drug conditions being randomly determined. During the second visit, the children received that agent not given during the first visit. Baseline physiologic data was obtained at the beginning of each visit and the physiologic measures were again recorded during topical and local anesthesia administration, high-speed tooth preparation, and at the end of the dental appointment. The results indicated that the frontalis muscle activity and cardiovascular parameters were significantly affected by the drug and dental procedures. Oxygen saturation was least affected. The frontalis muscle appears to be a sensitive physiologic parameter to monitor during conscious sedation as an index of the amount of patient relaxation.

Few sedation studies involving children have reported indices of safety such as the recording of vital signs. The primary focus of the great majority of studies is on the subjective effect of the medication on the behavior of the child. Studies that have reported vital signs or other physiologic parameters usually indicate little or no changes in physiologic parameters.[1-9] Changes that have been noted were usually transient (eg, change in heart rate) as a function of dentally imposed stimuli such as the insertion of a mouth prop.

Two studies have reported incidences of oxygen desaturation as measured by pulse oximetry.[17] Mueller et al.[7] investigated the effects on oxygen saturation of either alphaprodine (1.0 mg/kg) or chloral hydrate (100 mg/kg), both of which were supplemented by nitrous oxide/oxygen (50: 50) in children aged two to six years. Oxygen desaturation was defined as any "sustained" (three seconds or more) level below 95%. There was no control group nor was oxygen saturation measured before the administration of the agents. All of the patients in the alphaprodine group (20) and seven of 20 in the chloral hydrate group exhibited oxygen desaturations despite the use of 50% oxygen in both groups. No detectable changes were noted for heart rate, respiratory rates, and blood pressure in either group.

Similarly, Whitehead et al.[1] compared the effects of chloral hydrate (50 mg/kg) and hydroxyzine pamoate (25 mg) supplemented with nitrous oxide/oxygen (40: 60) to nitrous oxide/oxygen (40: 60) alone on oxygen saturation, heart and respiratory rate, and blood pressure in children aged two to five years. Their definition of oxygen desaturation was identical to that of Mueller. Again, there was no control group who did not receive any drug. They reported that two of 12 patients in the chloral hydrate-hydroxyzine group experienced oxygen desaturation; however, none of the 12 patients in the nitrous oxide/oxygen group had desaturations. Both studies did not indicate if patient movements were related to the desaturations. It is possible that miniscule patient movement occurred and was responsible for the incidences falsely reported as oxygen desaturations.

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Two recent studies have focused on the use of electromyographic (EMG) activity of facial musculature for monitoring the depth of general anesthesia and patient responsiveness. [10,11] There have been no studies in the literature on the use of EMG activity of facial muscles in conjunction with other physiologic parameters in children who were sedated for dental treatment

The purpose of this study was to determine if the frontalis EMG activity is a sensitive physiologic index of patient responsiveness or depth of sedation during dental appointments. Additionally, the relationship between frontalis EMG and other physiologic responses was evaluated.

MATERIALS AND METHODS

Ten children whose ages ranged from 20 to 37 months (mean age 27.7 ± 4.2 months) participated in this study. Each required restorations or extractions of a minimum of four teeth. The children were healthy, lacked allergies to any medications, and did not take medications for any other condition. They were recruited into the institutionally approved study after a routine dental examination during which they exhibited uncooperative behavior. The behavior typically involved crying, repeated attempts to escape from the dental chair, lack of compliance to commands, and interfering hand and body movements.

The study was a double blind cross-over design. Each child was scheduled for two operative appointments with a minimum of one week separating each visit During one appointment, a placebo (orange-flavored Tang) was administered. During the other appointment, chloral hydrate (40 mg/kg body weight) and hydroxyzine (Vistaril 2 mg/kg) were mixed with Tang and administered. Both the placebo and drug mixtures were adjusted to an equal volume (15 cc) and administered orally either by cup or syringed into the buccal vestibule as per patient receptiveness. The sequence of drug-placebo appointments was randomly selected for each patient The same operator was used throughout the study and was blinded as was the patient and parent to the fluid administered to the child. The children were nil per os from midnight before the morning of each appointment All appointments began at 7:00 AM or 10:30 AM and were usually completed within two hours. The time of the appointment was held constant for any given child.

The following procedure occurred at each appointment The child was weighed and taken with the parent to the dental operatory. Baseline information was obtained for blood pressure (Dinamap, Model 1846-SX), heart rate and peripheral oxygen saturation (Nellcor pulse oximeter Model N-100), expired carbon dioxide concentration (Datex CO2 Monitor, Model 223), and integrated frontalis electromyogram (Datex Anesthesia and Brain Monitor, ABM-II). The appropriate sized inflatable blood pressure cuff was always 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. Five EMG leads were placed according to manufacturers instructions with three across the middle portion of the forehead and one each on the mastoid prominence behind each ear. Technical information regarding the function of the ABM-II can be obtained from Edmonds et al.[11]

The child then was administered either the placebo or the drug and taken with the parent to a waiting area. The child remained with the parent in the waiting area for 45 minutes. Then the child was separated from the parent and returned to the dental operatory where all of the monitors were reattached to the child. The child was never restrained, unless their activity caused total interference of the operative procedure. The operator administered topical and local anesthesia and in some instances placed a rubber dam. Rubber dams were not used during extraction appointments. The teeth were either restored or extracted; however, high and low speed handpieces were used during each visit Following the operative procedure, the child was returned to the parent and monitored until the patient was stable and oriented. The child was then released into the care of the parent

Data for each physiologic parameter was collected during the baseline, topical and local anesthesia administration, initiation of tooth preparation with a high speed handpiece, and at the end of the operative procedures. All readings were obtained directly from the monitors except for the expired CO_2 and frontalis EMG. The latter was printed in small columnar plots by the monitor and represented amplitude-integrated EMG epochs of ten-second duration which later were linearly measured by a digitizing planimeter (Microplan II Image Analysis System, Laboratory Computer Systems). The output of the capnograph was also sent to a chart recorder and will be described as a pattern rather than as numerical points as described later. The raw data was collated and evaluated with a repeated measures analysis of variance to determine any significant difference among physiologic parameters at each above-indicated operative procedure as a function of drug/placebo visits.

RESULTS

Although ten children participated in this study, valid data was obtained from eight patients. One child was so disruptive during both visits that movement artifacts prevented collection of useable information. Technical difficulties with the **ABM-II** prevented the collection of valid data

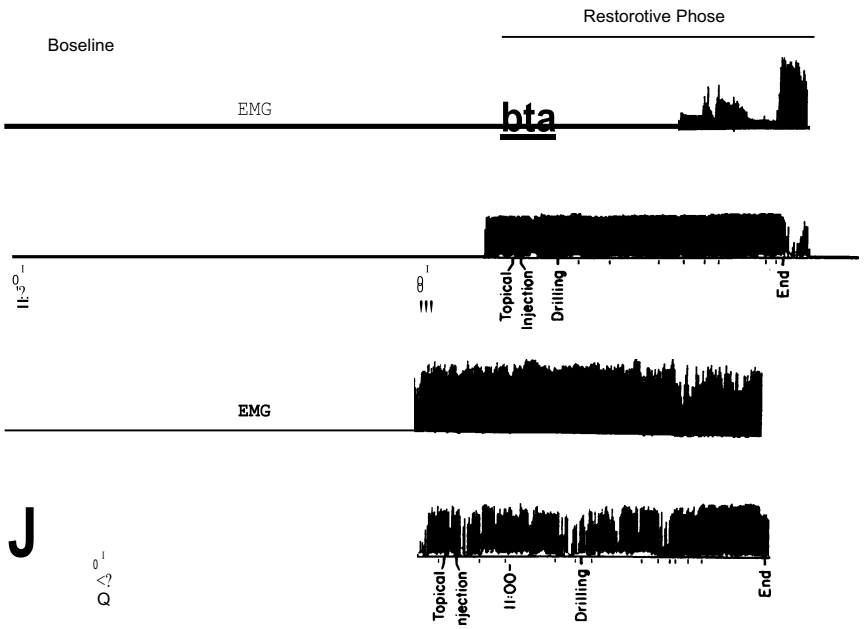

Figure 1. The frontalis EMG and expired CO_2 of a patient during chloral hydrate-hydroxyzine (upper *two* lines) and placebo *(lower two lines)* visits. Baseline values are shown as brief excursions located to the left of each line, whereas the excursions to the right represent values during the restorative phase of treatment The dental procedures (eg, topical) are marked below the CO_2 line of each visit.

during a session with another child and therefore no comparison could be made.

The integrated EMG was significantly decreased in comparing drug to placebo visits across procedures ($F = 9.52$, $P < 0.008$). A post-hoc analysis indicated that the significant difference occurred during the injection and at the end, although the topical and drilling procedures were nearly significant at the 0.05 level. Also, there was a significant within-subjects interaction effect involving the factors of dental procedures and drug conditions for the EMG ($F = 2.63$, $P < 0.044$).

The diastolic blood pressure also was found to be significantly decreased in comparing drug to placebo visits ($F = 4.88$, $P < 0.046$). A post-hoc analysis indicated that this difference occurred during the drilling procedure. All other variables (viz., systolic blood pressure, peripheral 0_2 saturation, and heart rate) were not significantly affected in comparing drug to placebo conditions.

A within-subjects analysis for the dental procedures revealed that the heart rate was the only physiologic parameter significantly affected ($F = 2.97$, $P < 0.028$). This difference was noted during both topical and injection procedures. Summary information is presented in Table 1.

There was variation in EMG and expired CO_2 patterns among patients as a function of drug or placebo regimen. Figure 1 shows the EMG and expired CO_2 of a sedated patient that physically appeared to be sleeping with eyes closed and little if any movement (upper two lines). Of note is the consistent, but significantly decreased EMG amplitude throughout the procedure compared with its baseline. Also, the expired CO_2, although slightly elevated compared with its baseline, was unbroken in pattern and very stable.

In contrast, the lower two lines of Figure 1 shows the same physiologic parameters of the same patient during

Table 1. Mean and Standard Deviation of Each Physiologic Parameter

Parameter	*Condition*	*Baseline*	*Topical*	*Injection*	*Drill*	*End*
EMG*	Placebo (P)	1.7 + .3	1.9 + .2	1.9 + .2	1.9 + .3	2.0 + .3
	Drug (D)	1.8 + .3	1.4 + .6	1.3 + .8	1.4 + .7	1.4 + .6
02 SAT	p	99.1 + .9	98.4 + 1.5	99.2 + .9	98.2 + 3.7	99.2 + 1.1
	D	98.4 + .9	96.7 + 1.2	97.8 + 1.2	98.7 + 1.2	98.1 + .6
Heart rate	p	119 + 16	147 + 23	149 + 22	158 + 20	145 + 12
	D	125 + 19	126 + 18	119 + 52	142 + 23	134 + 29
Systolic BP	p	106 + 15	113 + 13	111 + 12	123 + 24	100 + **42**
	D	110 + 20	98 + 10	102 + 13	107 + 20	106 + 14
Diastolic BP	p	62 + 11	71 + 10	73 + 14	78 + 18	64 + 5
	D	65 + 13	60 + 11	61 + 13	59 + 13	58 + 10

* Measured in linear units (millimeters).

the placebo visit. The EMG pattern during the operative phase was irregular and elevated in amplitude compared with its control. Likewise, the expired CO_2 is noted to have several breaks and fluctuated in concentration values. The latter was due to repeated bouts of crying (hyperventilation) and apnea due to breath-holding. This was a very typical pattern that was observed for any given patient, but varied among patients.

The 0_2 saturation was by far the most stable physiologic parameter observed in terms of percent change from baseline readings. The great majority of readings were between 100% and 96% saturation throughout the dental procedures. There were a total of 85 incidents of desaturation recordings below 95%; however, 76 (89%) were definitely associated with motion artifacts (patient movements). Six incidences (7%) appeared to be real desaturations (none <90%) with four of those occurring during sleep associated with the placebo appointment and two during sleep associated with the drug appointment. The remaining three incidences were associated with the placement of the rubber dam and breath holding in one patient.

DISCUSSION

This study was designed to describe the influence of conscious sedation that used relatively low dose sedative agents on multiple physiologic parameters including the activity of facial musculature. Because of the doses of the sedative agents chosen and the young age of the children as a group, it is not surprising that one child was unmanageable resulting in an inability to collect valid data.

The EMG and heart rate parameters were significantly influenced by the dental procedures. Heart rate has been reported to be labile and procedure-dependent by other investigators who used similar sedatives in higher dosages.[5] Overall, the EMG was affected by the sedative in that most children were found to have decreased muscle activity when given the sedative medication compared with their baseline or placebo activity. This suggests that the children were more relaxed during the sedation visit compared with the placebo visit.

The individual variability pattern seen between patients receiving a low, but single dose of medication supports known pharmacologic principles associated with a dose response curve in that a relatively low concentration of a drug would be expected to produce more variable behavioral (response) effects. It should be noted that the overall EMG pattern for any given patient receiving sedative medication remained sensitive, albeit somewhat depressed in most cases, to oral manipulation (viz., incidences such as "open your mouth" commands and placement of the rubber dam).

On the other hand, the EMG activity consistently increased and usually remained elevated throughout the operative visit when a placebo was given. Thus, the EMG appears to be a useful index of an individual's physiologic responsiveness to dental procedures and sedative drugs. Responsiveness or sensitivity in this sense would represent an increased rate of change in the measurement of a parameter as a function of experimental paradigm. Interestingly, the forehead EMG has been reported to have consistently high absolute reliability coefficients under multiple stimulus conditions. [12]

The clinical significance of this observation is most important as the EMG parameter provides a possible index of the depth of sedation. A serendipitous finding of the primary author highlighting the significance of the EMG's sensitivity is that the depth of depression of the EMG appears to correlate well with the integrity of the oropharyngeal reflexes. A poignant example is a child who was sedated to a level which approximated the patient in Figure 1. A couple of drops of water not picked up by high speed evacuation during the rinsing of an etched tooth was noted to pass into the pharynx. The breath sounds via the precordial lead indicated an abrupt apneic response for approximately five seconds followed by strong coughing response. Normally, the water would have been swallowed without incident.

One of the principal tenets of guidelines for conscious sedation is the patient's ability to independently maintain their airway.[13] Obviously, the child in the example had reflexes that were slightly depressed, although functional. Therefore, the EMG of facial muscles may be useful as to the degree of responsiveness of oropharyngeal and laryngeal reflexes. Attempts to identify a relationship between the two should be actively pursued for obvious reasons. Its value has been noted in many paradigms including those with emotional and painful stimuli.[14]

The cardiovascular responses were also indicative of patient responsiveness. The heart rate and blood pressure were observed to be both transiently responsive to particular oral stimuli (eg, injection or mouth prop insertion) during sedative sessions and more consistently elevated compared with baseline in placebo sessions, especially during the drilling phase. For an adequate description of changes in cardiovascular parameters, it is imperative that baseline values be obtained; otherwise, significant changes may not be appreciated.[2] In most cases, baseline blood pressure parameters are readily obtainable from the most recalcitrant of patients when they are held by their parents and a nonthreatening posture is taken by the operator. Although there was great variability within these cardiovascular parameters between patients, this study seemed to suggest that any given patient appears to have functional ranges and degrees of sensitivities that are relatively characteristic of the individual. This perception

needs to be addressed and scrutinized under more rigorous controlled conditions.

There were many instances of oxygen desaturation, but the great majority were associated with patient movement The amount of movement may be quite insignificant such as a slight flexing of the toes (this sensitivity may vary with different pulse oximeters), yet the temporary desaturation may be troublesome to the operator if the latter was not aware of the slight movement. In reality, the oxygen saturation in this study was extremely stable both across and within patients. There was essentially no difference between sedative and placebo sessions in terms of this parameter.

The patterns from the capnograph were quite characteristic of the clinical behavior exhibited by the child. During periods of crying when the majority of the expired air was routed primarily through the mouth (even with the rubber dam in place), there was considerable variation in the volume of expired air and concentration of CO_2 detected. Short apneic periods associated with breath holding or intense crying were also noted. Both of these conditions resulted in trended patterns of broken (breath holding) and variable concentrations of expired CO_2 When the child was quiet during placebo or sedative sessions, the pattern was one of stability or progressive and mild elevation over time, respectively. Slight head repositioning of the quiet child that resulted in a partially patent airway (as detected with the precordial lead) would yield a trended pattern of slightly decreased amplitude. Therefore, the capnograph is an excellent monitor for evaluation of the airway in that it responds immediately (most capnographs have an apneic mode that signals an alarm within a very brief period), indirectly indicates the patency of the airway, and signals changes in CO_2 concentrations that may be clinically important (eg, hypoventilation or early detection of malignant hyperthermia).[15,16]

In summary, this study hasshown that clinically relevant changes associated with both placebo and sedative conditions can be detected with multiple physiologic monitors (noninvasive). Baseline readings must be obtained before the initiation of any session in order to appreciate changes in physiologic parameters as a function of medication and/or dental procedures. The integrated EMG and cardiovascular parameters appeared to be the most sensitive in terms of physiologic changes per unit of time during experimental conditions with the pulse oximeter being the least sensitive. The EMG may be a valuable asset to patient monitoring if it can be shown to be a reliable index of pharyngeal integrity. Further definitive studies aimed at identifying this relationship and whether or not a threshold can be determined that separates conscious from deep sedation or general anesthesia need to be done. The capnograph is an excellent monitor and in conjunction with the pulse oximeter appears to be a clinically pertinent combination of monitors.

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