Facial electromyography and chloral hydrate in the young dental patient

Stephen Wilson, DMD, MA, PhD

Abstract

The purpose of this report is to describe facial electromyography (EMG) as a monitoring technique and to demonstrate the relationship of EMG amplitude to rated patient behavior during sedative trials using variable doses of chloral hydrate (CH) [25, 50, and 70 mg/kg]. Twenty healthy, uncooperative children (mean age = 30.7 ± 4.8 months) participated in this institutionally approved double-blind, repeated-measures study. Following baseline vital signs, administration of CH, and a 45-min period, the children were secured in a Papoose Board® (Olympic Medical Group, Seattle, WA) with electronic monitors attached including the EMG. EMG amplitude was recorded continuously by computer and each visit was videotaped for later analysis of behavior using the Ohio State University Behavior Rating Scale (OSUBRS). Statistical analysis using SPSS/PC+® V2.0 (SPSS Inc., Chicago, IL) included descriptive statistics of the study sample, one-way ANOVA, and Pearson Product-Moment Correlation Coefficient to determine differences in EMG amplitude as a function of CH dose and associations between per cent of rated behavioral categories of the OSUBRS to EMG amplitude, respectively. The results indicated a significant difference in EMG amplitude, per cent crying and quietness as a function of dose ($F = 3.87$, $P < 0.03$; $F = 4.64$, $P < 0.01$; $F = 3.38$, $P < 0.04$, respectively). Scheffe post-hoc analysis indicated that the difference was between 25 and 70 mg/kg doses. Significant correlations were noted between EMG amplitude and per cent crying and quietness ($R = 0.640$, $P < 0.001$; $R = -0.664$, $P < 0.001$), respectively. The findings suggest an association between EMG amplitude and behavior, which may be of clinical value compared to other electronic monitors during sedative trials. (Pediatr Dent 15:343–47, 1993)

Introduction

The facial muscles develop from the second branchial arch and are somewhat unique from other somatically derived muscles. For example, they have fewer muscle spindles, which apparently provide minimal, if any, control in facial muscle function. Electrical monitoring of facial muscle activity (electromyography) has been shown to be beneficial during various clinical states including general anesthesia and coma.[1]

Considerable information supports the study of psychophysiological responses to emotional expressions in humans.[2,3] Although current knowledge in the area of electromyography (EMG) of facial muscles may be considered primarily of research interest, it may be useful in monitoring patient responsiveness in specific clinical situations. For example, Nishino et al.[4] used electromyography to study the depression of the swallowing reflex during nitrous oxide sedation. They inserted a small catheter through the naris to a level of the epipharynx, taped the mouth closed, and used a nasal mask to administer oxygen and nitrous oxide. Different volumes of water were injected randomly in early expiration phases while a submental electromyogram was used to detect and measure latency of swallowing. They found that with progressively larger boluses of water, the latency to swallow decreased; however, the latency was longer with 50% nitrous oxide than with 100% oxygen for corresponding volumes of injected water. Also, the number of swallows was fewer for nitrous oxide than for oxygen.

The EMG also has been useful in other clinical situations.[5,6] The EMG has been purported to be an index of patient relaxation or excitability during sedative trials.[7,8] The purpose of this report is to describe electromyograpic responses as recorded by the Datex Anesthesia and Brain Monitor (ABM-II®—Datex Instrumentation Corp., Helsinki, Finland) in sedated pediatric dental patients.

Methods

Sample

Twenty healthy but uncooperative children participated in this double-blind study using chloral hydrate (CH). All parents gave informed consent for their children to participate in this institutionally approved study. The children were found to exhibit uncooperative behavior when examined during an initial visit. The extent of their dental caries varied, but usually involved a minimum of 4 of 6 sextants of teeth needing restoration or extraction. The children were healthy, had uncompromised airways (i.e., no enlarged tonsils) and had no known allergies. Procedures were designed to conform with the American Association of Pediatric Dentistry guidelines for conscious sedation.[9]

Clinical procedures

Although the details of this report have been described previously,[10] they are summarized as follows. Each child received CH in one of three dosages (25, 50, or 70 mg/kg) at each of three appointments with dosage varying by

child and visit as determined from a table of random numbers. No child requiring multiple visits had the same dose for any visit.

This investigator was the sole operator. Children were instructed to be NPO from midnight and all appointments began at 7:00 am and usually were completed within 2 hr. The placebo was Tang,® which also was used to flavor the CH. Usually one week separated each visit.

Baseline weight, systolic (SYS), diastolic (DIA), heart rate (HR), oxygen saturation (O_2), carbon dioxide concentration (CO_2), and integrated EMG (Datex Anesthesia and Brain Monitor, ABM-II) were obtained. The five EMG leads of the ABM-II 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 received either placebo or CH, waited 45 min, and then was restrained in a Papoose Board® (Olympic Medical Group, Seattle, WA). The operator administered topical and local anesthesia (usually not exceeding 1 carpule of Xylocaine 2% with epinephrine 1:100,000) and in most instances, placed a rubber dam. The teeth were either restored or extracted. When the operative phase was completed, the monitors were detached and the child returned to the parents. Once stable and oriented, the child was released with appropriate postoperative instructions.

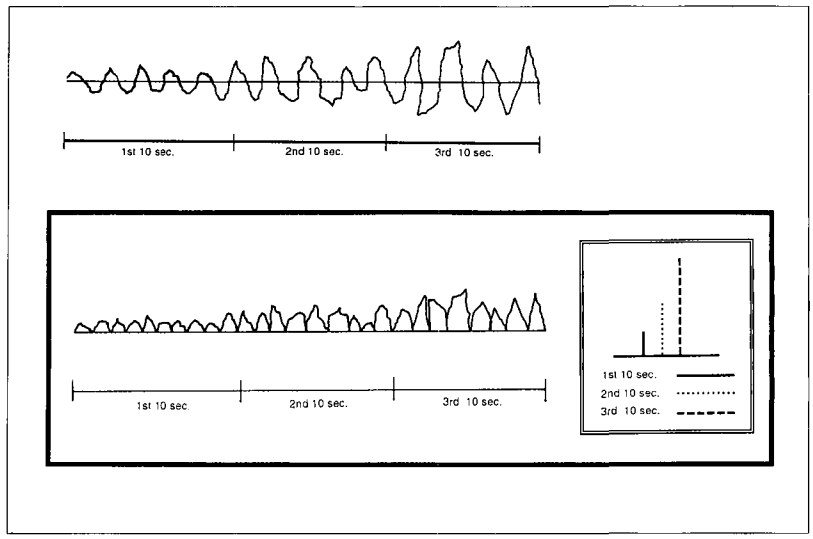

Fig 1. Schematic of ABM-II Electromyographic Function. The AMB-II monitor receives the raw signal from the patient. This is represented as an alternating waveform that is increasing in amplitude over a 30-sec period (top line). The raw signal is rectified (all excursions below the line of the raw signal are reversed to be above the line—this is shown as the signal in the bold box) and the area under each excursion is integrated as microvolts over a 10-sec period. The integrated microvolts are converted to a digitalized log-linear scale whose value for each 10-sec period is transmitted to a computer for later analysis. Also, the integrated signal is printed in a histogram format. Each vertical excursion in the histogram represented a 10-sec period of the integrated signal (this is shown schematically in the small double-lined box).

Data analysis

Data for each physiologic parameter were collected either continuously or every 5 min, depending on the monitor and its function. All readings were obtained directly from the monitors except for the frontalis EMG amplitude.

The EMG was integrated over 10-sec epochs, digitalized, and printed in small columnar plots on a chart recorder. Each column represented amplitude-integrated EMG epochs of 10-sec duration. The computerized value of the EMG amplitude is a log-linear conversion of the microvolt signal. Edmonds et al.[11] have reported the technical information regarding the function of the ABM-II.

A histogram of the EMG amplitude for the visit was automatically generated via Datex software. Additionally, the magnitude of the column was transferred on-line by the monitor and stored as an ASCII data file in a computer. An area-under-the-curve conversion was completed to determine an averaged overall EMG score for each patient visit. A diagrammatic summary of the EMG analysis can be seen in Fig 1.

Each visit was videotaped for later analysis of the behavior using the Ohio State University Behavior Rating Scale (OSUBRS). The OSUBRS was developed primarily to evaluate the behavior of a child restrained in a Papoose Board and has four behavioral categories that are rated continuously and are mutually exclusive.[12] The behavioral categories are defined as 1) Q = quiet with no movement; 2) C = crying with no movement; 3) M = struggling movement only with no crying; and 4) S = struggling movement and crying. Struggling is any repetitive movement of the feet or head and/or postural flexing (arching of back with the chest pressing against the abdominal and chest wrap) against the Papoose Board.

An evaluator trained in the use of the Automated Counting System (JAGTECH, Rockville, MD) and the OSUBRS rated the videotapes. The rater was blind to the drug dose, had participated in a minimum of three behavioral rating studies prior to this study, and had reliability assessed previously, consistently performing at better than 90% proficiency.

To standardize the length of behavior rating, each visit was evaluated for 30 min, although any given visit may have lasted longer. Because of individual differences in behavioral responses during any given visit or across visits, the duration of each behavioral category was converted to a per cent for the duration of each rated visit.

Descriptive statistics were used to characterize the sample of children. A one-factor ANOVA was used to analyze the EMG amplitude and the per cent of crying, movement, quiet, and struggling behaviors as a function of drug dose. An a priori level of statistical significance was set at 0.05.

Results

The mean age and weight of the children was 30.7 ± 4.8 months (range = 21 to 38) and 13.8 ± 1.8 kilograms (range = 11 to 17), respectively (Table 1). Twelve males and eight females completed 17 visits each during which the dose of CH was 25 and 50 mg/kg and 11 visits at a dose of 70 mg/kg. Although the behavioral categories were rated for each of those visits, technical difficulties with the EMG resulted in 13 analyzed visits each for the 25 and 50 mg/kg doses and 9 visits for the 70 mg/kg dose. The individual statistical analyses were based on these observations.

Table 1. Descriptive statistics of patient sample

Variable	*Mean ± SD*	*Range*
Age*	30.7 ± 4.8	21–38
Weight†	13.8 ± 1.8	11–17

* In months; † In kilograms.

A one-way ANOVA for the overall EMG amplitude and each category of behavior as a function of dose indicated that the overall EMG amplitude, per cent crying, and per cent quiet were significantly affected by drug dose ($F = 3.87$, $P < 0.03$; $F = 4.64$, $P < 0.01$; $F = 3.38$, $P < 0.04$, respectively). Per cent movement and per cent struggle were not significantly affected by drug dose, although these behaviors were least often observed. In general, as the dose of CH increased, the overall EMG and per cent crying decreased and the per cent quiet increased. A Scheffe post-hoc analysis indicated that the 25 mg/kg significantly differed from the 70 mg/kg dose. This analysis is summarized in Table 2 and Figs 2 and 3.

Table 2. ANOVA of behavioral and electromyographic data

*Variable**	*Dose*	*Mean ± SD*	*F*	*P*
% Crying†	25	45.7 ± 23.6		
	50	34.9 23.2		
	70	18.6 21.7	4.64	0.01
% Move	25	.33 .68		
	50	.42 .59		
	70	.69 .75	.96	0.38
% Quiet†	25	47.6 26.5		
	50	54.3 25.4		
	70	74.2 29.2	3.37	0.04
% Struggle	25	6.2 5.6		
	50	15.1 20.9		
	70	12.3 28.6	.92	0.40
EMG†	25	67.3 28.3		
	50	54.8 20.0		
	70	39.1 ± 19.4	3.87	0.03

* The behavioral data is expressed as a per cent. † For these variables, the 25 mg/kg group differed significantly from the 70 mg/kg group.

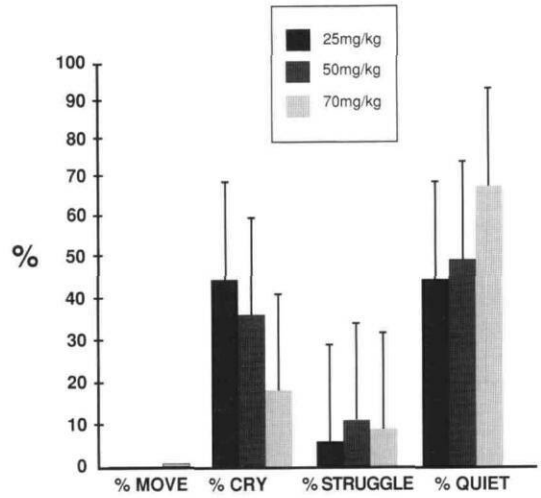

Fig 2. Bar graph illustrating mean per cent (± standard deviations) of each operationally defined behavior for a 30-min period when dental care was delivered as a function of chloral hydrate dose

For the available data, a Pearson correlation coefficient indicated that the association between per cent crying, per cent movement, per cent quiet, per cent struggle and overall EMG amplitudes were 0.640 ($P < 0.001$), -0.254 (N.S.), -0.664 ($P < 0.001$), and 0.201 (N.S.), respectively. This finding indicates a significant relationship between per cent crying and per cent struggling to that of overall EMG amplitude. Thus, as the per cent of crying increased, the EMG amplitude increased or as the per cent of quiet increased, the EMG amplitude decreased.

Discussion

The behavioral data indicated that the per cent quiet and per cent crying were the two prominent response modes exhibited in this study. Per cent struggle occurred less often and per cent movement was almost nonexistent. This pattern of behavioral categories is consistent with previous studies in our clinic (unpublished results).

Generally, as the dose of CH increased, the per cent of crying decreased and the per cent of quietness increased. For instance, at the 25 mg/kg dose, the per cent of crying and quiet were almost equal

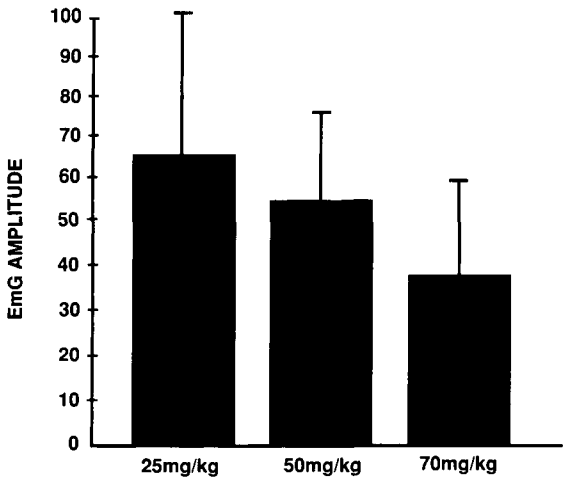

Fig 3. Bar graph illustrating mean EMG amplitude (in the ABM-II log-linear units representing microvolts) integrated over the entire operative portion of the dental visit as a function of chloral hydrate dose. The error bars represent 1 standard deviation.

and accounted for the majority of behavior exhibited, but at 70 mg/kg the per cent of quietness accounted for greater than 70% of the behavior with crying and struggling comprising the balance.

Some behavioral categories were associated with the overall EMG amplitudes under the conditions studied. In general, as the dose of CH increased, the overall EMG amplitudes decreased, which suggested more relaxation and quietness. This corresponded to periods of decreased per cent crying and increased per cent quietness. Since r^2 accounts for the total variance between two variables and the r value of per cent crying and per cent quiet each were greater than 0.64, independently, they represented at least 41% of the variance associated with the overall EMG amplitude, despite the fact that the EMG was recorded for the entire restorative visit and the behavior was rated for only the first 30 min of a visit.

The integrated EMG, when illustrated in graphic form can be assessed visually for any given restorative visit. The assessment rapidly relates the patient's responsiveness over the visit period. This has been referred to by the author as a "signature" of the patient's activity for any given visit.[8] It also demonstrates patient responsiveness to dentally imposed stimuli.

Fig 4 shows the trended EMG patterns of three patients. The panel illustrates the EMG patterns of a patient over three visits. The visits progress from top to bottom as 25, 50, and 70 mg/kg. The EMG amplitude is represented by the height of the patterns with decreasing amplitude corresponding behaviorally to patient relaxation and/or sleep. Time is represented on the abscissa going from left to right. Therefore, each line begins as a small blip on the left that represents baseline with the much broader pattern representing the restorative phase located to the right. There is an obvious dose-response effect observed across visits in this patient. This can be seen as a pattern of decreasing EMG amplitude in comparing the first visit to the last (25 to 70 mg/kg, respectively) during the restorative phases.

Also noteworthy are the changes in EMG amplitude as a function of dental procedures. For example, the three arrows pointing to the base of the 70 mg/kg visit (Fig 4) indicate the onset of topical and local anesthesia delivery (light dotted arrow), placement of rubber dam (black arrow), and initiation of tooth preparation (dark dotted arrow). Furthermore, there is a tendency for less responsiveness (decreased EMG amplitude) to these stimuli as the dose of CH increases.

Under the conditions of this study, the moderate association would suggest that the EMG amplitude is a relatively good, unbiased, and objective indicator of patient behavior during a given visit. In fact, as the child begins to drift into quietness and appears to be sleeping, the EMG amplitude tracks the patient's state of relaxation by decreasing in amplitude.

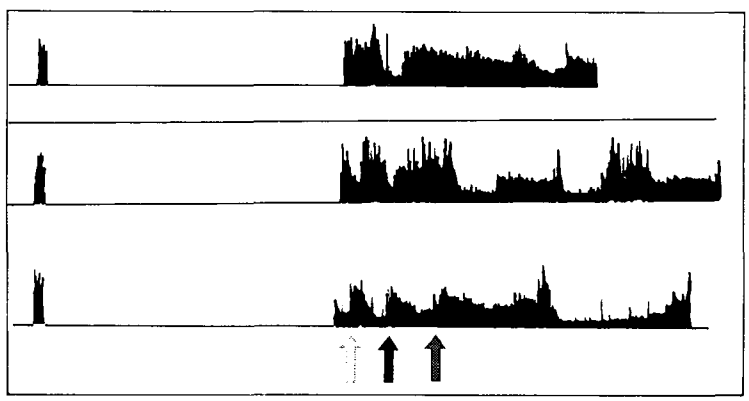

Fig 4. Trended EMG patterns of a patient over three visits. The patterns of each visit representing 25, 50, and 70 mg/kg of chloral hydrate, respectively, progresses from top to bottom. The EMG amplitude is represented by the height of the patterns with decreasing amplitude corresponding behaviorally to patient relaxation and/or sleep. Time is represented on the abscissa going from left to right. Therefore, each line begins as a small blip on the left, which represents baseline; the much broader pattern located to the right represents the restorative phase. There is an obvious dose-response effect observed across visits in this patient. Also noteworthy are the changes in EMG amplitude as a function of dental procedures. For example, the three arrows pointing to the base of the 75 mg/kg visit (lower pattern) indicated the onset of topical and local anesthesia delivery (light dotted arrow), placement of rubber dam (black arrow), and initiation of tooth preparation (dark dotted arrow), respectively.

Increased CH dosage led to periods of substantially reduced EMG amplitudes in this study. These periods of reduced EMG corresponded behaviorally to either a quiescent state or sleep and most frequently occurred in the latter half of the restorative visit. Many but not all patients receiving higher doses of CH were exceedingly relaxed (or asleep) when separated from their parents. Oftentimes, placing a child into the Papoose Board produced little struggling, especially when the dose of CH was 70 mg/kg. At that time, the EMG amplitude was visibly reduced compared with baseline amplitudes. Brief periods of increased EMG amplitude corresponding to struggling and crying often followed more noxious stimuli such as the injection of local anesthesia.

It should be emphasized that a classic dose-response effect was not realized for every patient. Some children who received higher doses of CH struggled and had maximal EMG amplitudes, while others were quiet and had reduced EMG amplitudes following administration of the lowest dose. These are not unexpected findings for sedation studies because of one's inability at times to control certain variables (i.e., temperament, parent-child interaction, coping skills, and previous experiences).

The relative state of relaxation is reflected in the absolute EMG amplitude as a function of time. However, more noxious or intense stimuli may bring about a rapid rise in the EMG amplitude and the child may respond by crying or struggling. Similar facial EMG fluctuations as a function of more painful, manipulative stimuli have been observed even under the conditions of general anesthesia when there is a total lack of behavioral response.[6]

A possible helpful role for the EMG is its ability to indicate the depth of sedation. If the depth of sedation, according to the EMG amplitude, is increasing toward very deep sedation or general anesthesia, steps could be taken to reverse the trend and "lighten" the patient. In comparison to other monitors such as the pulse oximeter and capnograph, the EMG provides—albeit indirectly and to a limited extent at its current level of sophistication—an opportunity to characterize the level of patient sedation or relaxation. It may provide a threshold or warning to the clinician.

It is not clear if the EMG would be able to discriminate between "conscious" and "deep" sedation, but if the sensitivity and selectiveness of such a system could be developed, the state of the art of patient monitoring and safety could be vastly improved. It would be interesting to determine if certain parameters (e.g., amplitude and frequency) of the EMG of selective facial muscles could be associated with the child's ability to control the airway, aiding in discriminating between levels of sedation. In a rat model, preliminary research indicates that the EMG activity of pharyngeal and digastric muscles is associated with relative depths of sedation.[13] Further development of the EMG as a monitoring tool for sedation seems warranted.

Conclusions

1. Significant differences were found for EMG amplitude, per cent crying and quietness as a function of CH dose. The differences for each of these variables occurred only between the 25 and 70 mg/kg doses.
2. There were significant positive and negative associations between per cent crying and per cent quiet behaviors, respectively, and the EMG amplitude. As the per cent of crying increased, the EMG amplitude increased and when the per cent of quietness increase, the EMG amplitude decreased, suggesting a correspondence between periods of quiet behavior and patient relaxation as determined by the EMG.

Dr. Wilson is associate professor and director, Advanced Pediatric Dentistry Program and Research Department of Pediatric Dentistry, College of Dentistry and Columbus Children's Hospital, The Ohio State University, Columbus, Ohio.

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