ELECTROENCEPHALOGRAPHIC FREQUENCY SPECTRUM ANALYSIS DURING ETHER AND CYCLOPROpane ANESTHESIA

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Changes in cortical activity during anesthesia have been described by a number of investigators (1-5). The descriptions are qualitative and note the change in frequency, wave form, and amplitude that occurred at various depths of anesthesia. Dawson and Walter pointed out the difficulty of interpreting electroencephalographic complexes visually and defining the frequencies that are summed to produce different complexes and at the same time appreciate the amplitude of each of these frequencies (6). In order to define more accurately the characteristic electroencephalographic pattern associated with the analgesic state of diethyl ether anesthesia we submitted this electroencephalographic pattern to frequency spectrum analysis (7). We were able to present a quantitative description of this pattern by using the Spencer Kennedy Laboratories filter. The purpose of this study is to extend these determinations to include the electroencephalographic changes noted with diethyl ether anesthesia and cyclopropane anesthesia, from emergence from very deep surgical anesthesia to analgesia using ether and from deep anesthesia to very light surgical anesthesia using cyclopropane.

Method

Observations were made on two healthy young (22 and 26 years) volunteers, one of whom received diethyl ether and the other cyclopropane as the sole anesthetic agent. The subjects were anesthetized to electroencephalographic level 6 and allowed to recover. Electroencephalographic recordings were made in a shielded room from fronto-central no. 25 needle-electrodes on a Mederaft Electroencephalograph Model D. Analysis of the electroencephalographic frequency spectrum was made by an Offner Electronics Frequency Analyzer Type 830 which was standardized with a Hewlitt Packard Audio Signal Generator Model no. 202B. The amplitude of the analyzer pen deflection was calibrated in microvolts at each frequency studied by feeding a known peak to peak sine wave signal into the electroencephalographic recorder and determining the relationship of signal strength to pen deflection. The electrocardiogram was recorded simultaneously on one

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TABLE I

AMPLITUDE (in Microvolts) SUMMATED FOR 10 SECONDS AT FREQUENCIES FROM 1.5 TO 30 CYCLES PER SECOND DURING RECOVERY FROM ETHER ANESTHESIA

<table>
<thead>
<tr>
<th>Time in Minutes After Decadolane</th>
<th>Frequency in Cycles Per Second</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.5</td>
</tr>
<tr>
<td>1.5</td>
<td>54</td>
</tr>
<tr>
<td>3.0</td>
<td>501</td>
</tr>
<tr>
<td>5.0</td>
<td>72</td>
</tr>
<tr>
<td>7.5</td>
<td>66</td>
</tr>
<tr>
<td>10.0</td>
<td>378</td>
</tr>
<tr>
<td>5.0</td>
<td>120</td>
</tr>
<tr>
<td>10.0</td>
<td>104</td>
</tr>
</tbody>
</table>

channel of the electroencephalograph recorder. Blood pressure was recorded at least every five minutes by sphygmomanometric technique. Premedication consisted of 0.6 mg. of atropine given intravenously 15 minutes prior to the start of anesthesia. After an awake pattern was obtained anesthesia was induced.

Ether.—Diethyl ether anesthesia was induced by a nitrous oxide-oxygen ether sequence. After the subject entered the stage of surgical anesthesia oral endotracheal intubation was performed. Lidocaine, 5 per cent, ointment was used on theuffed endotracheal tube as a topical anesthetic. All nitrous oxide was eliminated from the breathing mixture. Anesthesia was continued using a Feddbrinn closed circle-carbon dioxide absorber system until electroencephalographic level 6 was achieved.

![Fig. 1](http://anesthesiology.pubs.asahq.org/pdfaccess.ashx?url=/data/journals/jasa/931673/)
reached. The administration of ether was then discontinued, the expiration valve opened, and the oxygen flow was increased from 300 cc. to 2 liters per minute. This semiclosed system allowed the ether to be eliminated gradually. Continuous electroencephalographic recordings were started with simultaneous pattern analysis, using the frequency analyzer. Recordings were continued until the subject entered the stage of analgesia and responded to spoken voice.

The amplitude summated over 10 seconds at each frequency studied from 1.5 cycles per second to 30 cycles per second was calculated and tabulated at 30 second intervals from deep third stage anesthesia to analgesia (condensation of the data shown in table 1). From these data plots were made of amplitude versus frequency versus depth of anesthesia. From the plots of these variables a three dimensional model was constructed (fig. 1).

Cyclopropane.—Cyclopropane anesthesia was induced by a 50 percent oxygen and 50 percent cyclopropane mixture and continued using a Heidbrink closed circle-carbon dioxide absorber system with a face mask until the subject entered electroencephalographic level 6. The administration of cyclopropane was then discontinued and the expiratory valve opened. The oxygen flow was increased from 300 cc. to 1 liter per minute and the continuous electroencephalogram was recorded simultaneously in association with analysis by the frequency analyzer. Recordings were made until the subject entered light surgical anesthesia.

The amplitude summated over 10 seconds at each frequency studied from 1.5 to 30 cycles per second was calculated and tabulated at six levels of anesthesia corresponding to the six levels of cyclopropane anesthesia described by Possati and others (4). From these data (table 2) a three dimensional representation was drawn (fig. 2).

**RESULTS**

The changes in amplitude of various frequencies with time after discontinuance of ether anesthesia were tabulated (condensed data
shown in table 1), and a picture of a three dimensional model of these
data is shown in figure 1. In deep stages of ether anesthesia there is
an abundant amount of 1-2 cycle per second activity. As anesthesia is
lightened there is a decrease in the slow frequencies and an increase in
the fast 24 cycle activity. If plots are made of frequency versus depth
(time after discontinuance of ether) it can be seen from table 1 that
the 24 cycle activity decreased directly with increasing depth of anes-
thesia. The 6 cycle activity when plotted forms a bell shaped curve.
It reaches a maximum in moderately deep anesthesia and falls off in the
light and deep stages. The 2 cycle activity forms a sigmoid shape plot.
Its amplitude is low in light stages of anesthesia and rises to a maxi-
mum as anesthesia becomes deep. The solid representation of the
amplitude variation of each frequency permits one to grasp the
topography of these changes more easily.

![Cyclopropane Anesthesia](http://anesthesiology.pubs.asahq.org/pdfaccess.ashx?url=/data/journals/jasa/931673/)

**Fig. 2.**

Table 2 indicates the changes in amplitude measured at various fre-
quencies from 1.5 to 30 cycles per second during the recovery from
cyclopropane anesthesia. A three dimensional representation of these
data is shown in figure 2. This electroencephalographic pattern in
depth cyclopropane anesthesia consists predominately of 2 cycle ac-
tivity with little fast activity present. As anesthesia is lightened the
amount of fast activity increases, but fast 24 cycle activity character-
istic of light ether anesthesia is not noted. The topography of the
 electroencephalographic changes with varying depth of cyclopropane
anesthesia is different from that seen with ether. It will be noted from
table 2 that if the amplitude of the frequencies from 11.2 to 30 cycles
is summated the energy represented tends to decrease with increasing
depth of anesthesia.

No electrocardiographic disturbance or marked decrease in blood
pressure was noted during these studies.
Discussion

The amplitude expressed in microvolts peak to peak as calculated from the plot produced simultaneously on the electroencephalographic record by the frequency analyzer is a representation of the continuous peak to peak sine wave signal that would produce the same pen deflections. Activity at a specific frequency in the electroencephalogram may vary from moment to moment so that the amplitudes expressed are the average value occurring during a 10 second interval.

The peak frequencies of the analyzer are accurate to \( \pm 0.05 \) cycles per second. The band pass is much narrower than that of the modified Spencer Kennedy Laboratories filter we used in determining the frequency spectrum of the analgesia pattern. The Offner Electronics Frequency analyzer with its narrower band pass allowed us to obtain higher resolution of the analgesia pattern. For this reason the 24 cycle peak is much sharper and higher than that found with the previous method of analysis. This fact was appreciated and predicted in a former paper (7).

It may be that the large slow waves observed in the electroencephalogram were not analyzed accurately since it is possible to overload the system and obscure changes that occur at larger voltages. When the amplitude approaches the maximum recorded by the analyzer as it did in the slower frequencies it would be best to recalibrate the analyzer to handle these greater amplitudes.

It is difficult to give absolute values to the axis labeled "Depth of Anesthesia." Possati and others (4) found a straight line correlation between the depth of cyclopropane anesthesia as determined by electroencephalographic classification and the arterial blood cyclopropane level. We have plotted the six patterns of cyclopropane anesthesia on the depth of anesthesia axis, and, based on the work of Possati, Faulconer, Bickford and Hunter (4), one might consider the arterial blood cyclopropane level to be increasing linearly from one through six. The depth of anesthesia axis on the ether anesthesia model is expressed in time from discontinuance of ether anesthesia. Desaturation of the body is a hyperbolic function. If blood anesthetic levels were available it would permit us to give the depth of anesthesia absolute units in these studies.

An attempt was made to keep \( pO_2 \) and \( pCO_2 \) within normal limits by assisting respiration when necessary. It has been shown that \( CO_2 \) and \( O_2 \) have marked effects on the electroencephalogram (10). In order to rule out interference from these factors it is necessary to do blood \( CO_2 \) and \( O_2 \) determinations. The patterns recorded during both these runs appeared to be similar to those seen regularly during cyclopropane or ether anesthesia. Therefore, we believe these analyses are of typical electroencephalographic changes produced by these anesthetics.
The analgesic pattern represented in this paper has small secondary peaks at 7.1 and 5 cycles per second. These peaks were not noted in our earlier analyses of the analgesic pattern (7). Whether they are significant or represent artifacts remains to be determined. It may be that the higher degree of resolution offered by this method of analysis permitted us to detect these secondary peaks.

Servo anesthesia offers an immediate practical application of the data presented here. It has been possible to control depth of anesthesia by use of servo control (8). All agents can now be screened as outlined in this study and the data analyzed so that the optimal frequency to be monitored can be selected. Hunter has discussed the pitfalls that the research worker can fall into when evaluating a system in which there are three variables (9). Contour surfaces or similar representation will help avoid some of these errors and aid in selection of optimum conditions.

We believe that the use of the electroencephalogram and frequency spectrum analysis in this way offers a new approach to the study of anesthetic agents. The differences in topography between cyclopropane and ether anesthesia probably attest to a different mode of action of these agents or a different site of action. Perhaps the day is not far off when certain peaks and troughs in the topography of the frequency spectrum analysis of an anesthetic agent will be related to specific sites of action or perhaps to specific enzyme systems influenced by the anesthetic agents.

**Summary**

Frequency spectrum analysis of electroencephalographic changes during diethyl ether and cyclopropane anesthesia has been performed by the use of an Offner Electronics Frequency analyzer. The data thus obtained has been presented in tabular and three dimensional representation. The difference in the topography of the electroencephalographic changes produced by ether and cyclopropane may indicate a different site or mode of action of these agents.

**Acknowledements**

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**REFERENCES**