

ELECTRO-ENCEPHALOGRAPHIC PATTERN AND FREQUENCY SPECTRUM ANALYSIS DURING DIETHYL ETHER ANALGESIA * † ‡

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In 1883, von Marxow observed changes in the electrical activity of the brain during chloroform and diethyl ether anesthesia (1). It was not until 1931 that Berger used a recording galvanometer and noted specific variations in the electro-encephalographic pattern produced by scopolamine, cocaine, and chloroform (2). In 1937, Gibbs *et al.* reported the effect of several agents, including diethyl ether, on the electro-encephalogram (3). At this time, Gibbs suggested the possibility of employing electro-encephalographic techniques for controlling the depth of anesthesia. In 1949, Faulconer *et al.* suggested that a correlation existed between the depth of nitrous oxide anesthesia and the electro-encephalographic pattern (4). In 1950, Courtin described 7 distinct levels or patterns that occurred during diethyl ether anesthesia (5, 6). These patterns were reproducible and differed from the pattern seen in the conscious control. In 1952, Faulconer *et al.* determined the arterial blood-ether concentrations at each of these 7 levels of ether anesthesia (7). He found a direct correlation between the blood arterial ether concentration and the pattern seen on the electro-encephalogram.

The purpose of the authors in this study is to define the electro-encephalographic pattern occurring during stage I (analgesia) of diethyl ether and to determine the frequency spectrum of this pattern.

METHOD

These experiments were performed on 39 patients undergoing mitral commissurotomy for mitral stenosis and 1 patient undergoing pulmonary commissurotomy for pulmonary stenosis. Observations were made on 9 men and 31 women whose ages ranged from 18 to 53 years, with a mean age of 38 years.

Premedication consisted of 0.2 mg. of atropine sulfate given subcutaneously 1 hour prior to anesthesia. Following 75 to 100 mg. of

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† These investigations were aided by a grant from The New York Hospital-Cornell Medical Center Research Fund.

‡ Accepted for publication August 2, 1954.

thiopental sodium administered intravenously, ether anesthesia was induced with a nitrous oxide-oxygen-ether sequence until the patient entered stage III, plane 1. Following oro-endotracheal intubation in this plane, with the aid of topical anesthetic adjuvants, the depth of anesthesia was lightened until the patient responded to the spoken voice (Artusio, 9).

Following the introduction of the thiopental sodium, frontocentral No. 26 needle electrodes were placed in the scalp. Electro-encephalographic recordings were made with a standard two-channel Grass III D electro-encephalograph, calibrated at 50 microvolts deflection for 7 mm. and using a paper speed of 30 mm. per second. Permanent records were obtained throughout induction and periodically during the operation.

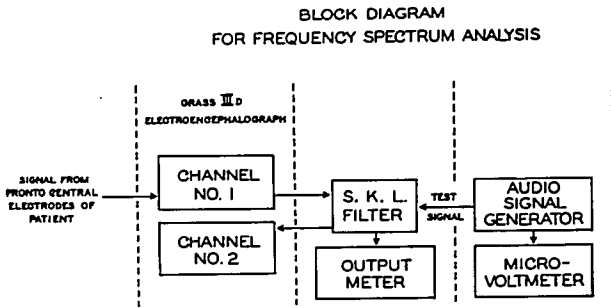


Fig. 1. Block diagram for electro-encephalographic frequency spectrum analysis.

Venous blood samples were drawn on 15 patients during surgery while they were responding to the spoken voice. Simultaneous electro-encephalographic tracings were taken. Blood-ether determinations were made, using a modification of the method of Ronzoni (9, 10). Eleven of these patients had postoperative awake electro-encephalograms recorded by the same technique.

Frequency spectrum determination of the electro-encephalogram was done on 9 patients during analgesia. Analysis was accomplished by feeding the output from channel 1 of the Grass III D electro-encephalogram into a modified Spencer Kennedy Laboratories filter which can be tuned to any frequency from 1.9 to 2,000 cycles per second. The output from the filter was then recorded on channel 2 for comparison and simultaneously the energy level was read with an output meter calibrated for each frequency with a Hewlit Packard Audio Signal Generator (fig. 1).

RESULTS

A stable electro-encephalographic pattern (fig. 2) was seen throughout the stage of ether analgesia (as described by Artusio, 9). Following the intentional establishment of surgical anesthesia (Courtin electro-encephalographic level 3), the patient was returned to the analgesic stage, whereupon the figure 2 pattern reappeared. The electro-encephalographic pattern had an amplitude of 30 to 40 microvolts and was of regular rhythmic sinusoidal oscillations at a frequency of 20 to 24 cycles per second. This pattern was consistent throughout ether analgesia and was independent of the duration of anesthesia. In stage I of diethyl ether analgesia, there was a marked absence of the slow frequencies, although minimal amounts of alpha activity occasionally were observed. As the anesthesia was deepened, the pat-

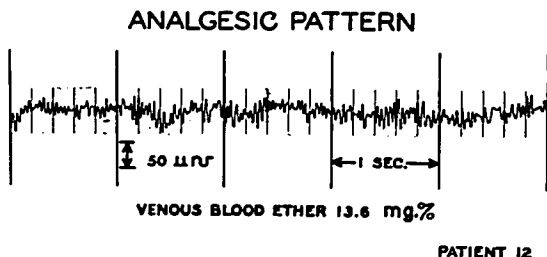


FIG. 2. Electro-encephalographic pattern during diethyl ether analgesia.

tern changed by the appearance of slower frequencies with a superimposed fast activity, and as anesthesia was progressively deepened, the fast activity disappeared and slower frequencies became dominant.

The frequency spectrum analysis done on the electro-encephalogram of 9 patients in stage I, plane 3 (analgesia) showed the predominant frequency of cortical activity to be 22 cycles per second (fig. 3). The peak activity averaged 17 microvolts, with a range from 12.5 to 22 microvolts. The electrical activity decreased on each side of the peak frequency and there were no secondary peaks noted as long as movement and muscle artifacts were not present. The 11 postoperative electro-encephalograms were all within normal limits and showed the alpha activity seen in conscious patients. They were distinctly different from the analgesic pattern.

Venous blood-ether determinations ranged from 2.0 to 17.6 mg. per cent. The average value was 10.2 mg. per cent and the mean value was 11.3 mg. per cent.

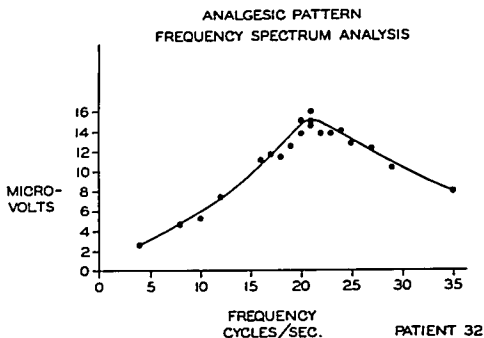


FIG. 3. Electro-encephalographic frequency spectrum curve.

DISCUSSION

We have presented a description of the electro-encephalographic pattern that is seen during diethyl ether analgesia. Although the stage of ether analgesia was described a number of years ago by Snow (11), in subsequent years it was not thought to be a practical level of anesthesia in which to accomplish surgery. The recent work of Artusio has shown that the analgesic stage is least upsetting to the compensatory mechanisms of the body as compared with deeper stages of diethyl ether anesthesia (9).

Analgesia exists as a definite stage in which past memory and orientation to place and time are intact. Special sensory modalities are intact in plane 3 of stage I, and have been described in detail elsewhere. Pain perception at this level is obtunded. Thus, although some cortical functions are impaired, it has been shown that this impairment is a selective phenomenon and a pure stage of analgesia does exist.

Fast cortical activity during induction has been described by Gibbs *et al.* However, the correlation of this pattern with the analgesic stage was not made. Courtin, in his work on diethyl ether anesthesia, did not note the fast frequencies we have observed. This perhaps may be explained if we compare the frequency response of the recording instrument he used with the frequency response of the Grass III D electro-encephalograph (fig. 4). The electro-encephalograph Courtin used falls to about 25 per cent of peak output at 20 cycles whereas the Grass III D is still at 100 per cent response at 20 cycles even with the muscle filter on (6, 13). This fact also may be the explanation for the failure of the appearance of compound waves during light surgical anesthesia in Courtin's study. The compound waves we noted con-

sisted of 2 to 4 cycles per second activity with superimposed 20 cycle per second activity. These waves are similar to the patterns described by Gibbs *et al.*, during diethyl ether anesthesia, and, of course, would be absent if the amplifier cut off below 20 cycles.

The majority of the patients in this series received 75 to 100 mg. of thiopental sodium prior to the introduction of ether. Several patients who received no thiopental sodium prior to the introduction of ether also showed exactly the same patterns. The electro-encephalogram pattern during ether analgesia was independent of the time interval following the injection of thiopental sodium and the pattern of ether analgesia, once established, can be maintained or reestablished at any time.

It is of interest that similar patterns have been observed under identical recording conditions in patients who were under nitrous oxide-oxygen-succinylcholine anesthesia (14).

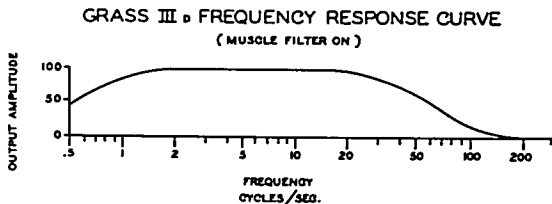


FIG. 4. Grass III D frequency response curve (by permission, Grass Instrument Company, Inc.)

Anesthetic agents are central nervous system depressants. Agents that depress the central nervous system cause a decrease in cortical activity. The pattern described here suggests that diethyl ether may have a primarily stimulating effect, or the change in the electro-encephalographic pattern represents a desynchronizing of the cortical activity.

Magoun, French, and Verzeano's recent work with animals shows that the ascending reticular formation is of importance during sleep and anesthetic stages (15, 16). They noted that lesions in this area produced slow patterns on the electro-encephalogram, typical of sleep or anesthesia, while stimulation or activation of this area produced, in the cat, desynchronization or fast activity in the electro-encephalogram of greater than 15 cycles per second. Magoun felt that afferent stimuli induce or contribute to wakefulness not by direct sensory discharge at the cortex, but by indirect excitation of the ascending reticular system.

If this work carries over to the human, with the findings presented, we have an attractive hypothesis. In analgesia, the ascending reticular system is not blocked as it is during sleep or surgical anesthesia.

On the contrary, it is activated; the patients are in a state of wakefulness, but yet they do not perceive pain, or if they do perceive it, they do not appreciate it.

From our data it can be postulated that diethyl ether exerts its effect at several places in the central nervous system. During analgesia a block occurs either at some point in the cortex, or between the cortex and the thalamus, so that pain is not appreciated. At this time, the ascending reticular system is not depressed. The pattern is 20 to 22 cycles per second and the patient is analgesic. As the concentration of diethyl ether is increased, the reticular system is depressed. Slow waves are noted on the electro-encephalogram; the patient is unconscious and in the stage of surgical anesthesia. Thus in surgical anesthesia the effect of diethyl ether is exerted in two places to block sensory impulses from reaching the cortex. One blocks the fibers coursing laterally and blocks them at the cortical level, while the other blocks them medially in the reticular substance.

Although the method described herein for the frequency spectrum analysis is not so rapid as some already described, it has the advantage of giving the microvolt activity at each frequency. It is a tedious process and requires the pattern to be kept stable for valid results. It is especially useful in the deeper levels of anesthesia where the cortical activity is paroxysmal. If correction is made for the band pass of the Spencer Kennedy Laboratories filter, the frequency spectrum curve will have a sharper peak than that shown in figure 3 (17). Naturally there will be variations in the microvolt activity between individuals, depending on many individual factors and placement of electrodes.

During the investigation of ether analgesia, we have been impressed with how well extremely poor risk patients tolerate this type of anesthesia. By using the electro-encephalogram as a monitor, it is possible, with the muscle relaxants, to extend this type of anesthesia to include those procedures requiring large muscular relaxation.

SUMMARY AND CONCLUSIONS

The electro-encephalographic pattern during diethyl ether analgesia consists of regular rhythmic sinusoidal oscillations at a frequency of 20 to 24 cycles per second and an amplitude of 30 to 40 microvolts. The average venous blood ether concentration at this level was found to be 19.2 mg. per cent.

A method of determining the frequency spectrum analysis of the electro-encephalogram with the aid of a Spencer Kennedy Laboratories filter has been described.

ACKNOWLEDGMENT

The authors wish to express their thanks to the Cambridge Instrument Company, Inc. for the use of some of the electronic equipment used in this study.

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