ELECTROENCEPHALOGRAPHIC PATTERNS DURING NITROUS OXIDE-TRIFLUOROETHYLVINYL ETHER ANESTHESIA

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Recently, a new anesthetic agent, trifluoroethylvinyl ether (Fluoromar®), has been introduced for clinical trial (1). Preliminary experiences with this agent in the laboratory and operating room have already been reported (2). Although examples of electroencephalographic patterns seen during anesthesia with this agent have been published (3), there is no detailed description of them. The purpose of this study is to describe the electroencephalographic patterns seen during nitrous oxide-trifluoroethylvinyl ether anesthesia and correlate them with clinical signs and depth of surgical anesthesia.

Method

Fronto-occipital electroencephalographic tracings were taken during nitrous oxide-trifluoroethylvinyl ether anesthesia in 20 unselected adult patients using the Edin Anesthesiograph. The types of operative procedures are listed in table 1. Meperidine, 75–100 mg., and scopolamine or atropine 0.4 mg., were used for preliminary medication in all cases. Anesthesia was started with nitrous oxide, 3 liters per minute, and oxygen, 1 liter per minute. About one minute later and before consciousness was lost, trifluoroethylvinyl ether was added to the anesthetic atmosphere in gradually increasing concentrations from a Heidbrink no. 8 incircle vaporizer. As the depth of anesthesia increased, the flow of nitrous oxide was decreased. Surgical anesthesia was maintained with nitrous oxide, 1 liter per minute, oxygen, 1 liter per minute, and trifluoroethylvinyl ether vaporized at a vaporizer setting of from 2 to 4. Concentrations of oxygen in the rebreathing bag were checked at intervals during maintenance anesthesia with a Beckman model D oxygen analyzer. At least 35 per cent oxygen was present at all times.

The duration of anesthesia varied from one and one-half hours to six and one-half hours with an average of three and one-half hours.

Electroencephalographic tracings were taken just prior to starting anesthesia, continuously during induction, and at 5 to 10-minute intervals during maintenance of anesthesia. Typical examples of these patterns are shown in figure 1.

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Six specific patterns were recognized.

First Pattern.—The first noticeable change in the electroencephalogram during anesthesia was the replacement of the normal resting alpha rhythm by fast frequency activity of 15–25 cycles per second, and a decrease in the voltage from control levels of 50–25 $\mu$V. to 25$\mu$V. or less. This first pattern was prominent only if the control electroencephalogram had demonstrated good alpha-wave activity.

Second Pattern.—As the anesthetic level deepened, slower frequency low voltage waves were superimposed on the fast activity of the previous level. These slower waves initially occurred at irregular intervals and at varying voltages, giving a spindling effect over a duration of 6–8 seconds. When this level was well established, the slower wave forms became very symmetrical with a frequency of 4–6 per second and a voltage of about 50 $\mu$V, and the pattern assumed a regular appearance. The voltage of the fast frequency background activity decreased as compared to pattern 1.

Third Pattern.—Two significant changes occurred as the next pattern developed. The fast background activity ceased, and the dominant wave forms developed a slower frequency and higher voltage. During the transition into this level, the wave forms were irregular with some notching and spindling. However, after the pattern was well established the waves became symmetrical in form with a frequency of 3–5 per second. The voltage varied from 75 to 125 $\mu$V.

Fourth Pattern.—As this pattern developed, the frequency slowed to 2–4 per second, and the voltage increased to 100–300 $\mu$V. The wave forms became irregular with little tendency to repeat themselves.

This pattern exhibited the highest voltage and greatest degree of irregularity of wave forms seen. During deeper levels of this pattern, the voltage began to diminish and the wave forms became even more irregular.
Fifth Pattern.—With the onset of this pattern, a certain degree of regularity returned to the electroencephalogram. Slow frequency, high voltage waves of long duration developed. These appeared at a rate of 1 every 1–2 seconds with a spread of about 1 second. Their voltage varied from 100 to 175 μv. Superimposed on this dominant slow

![Graphical representation of patterns 1 to 6](image)

**Fig. 1.** Electroencephalographic patterns during nitrous oxide-trifluoroethylvinyl ether anesthesia.
rhythm were waves of 3–5 per second frequency and 25–75 μv. amplitude. This faster activity was most prominent during the intervals between the larger, slower waves.

**Sixth Pattern.**—As anesthesia was deepened from the previous level, the frequency of the dominant slow waves decreased to 1 every 2 seconds. The superimposed 3–5 per second wave forms decreased in voltage to 25–50 μv. and appeared only in the intervals between the larger slower waves. The most prominent feature was the regularity with which the wave forms reproduced themselves.

**Clinical Signs**

**Consciousness.**—With the appearance of pattern 1, consciousness was lost.

**Eye Signs.**—Eye ball oscillation, lid reflex, and conjunctival reflex were active until the onset of pattern 2. Lacrimation continued until the high voltage 3–5 per second waves of pattern 3 were well established. Although pupillary dilatation increased with deepening anesthesia, it did not develop to the degree seen with ether anesthesia. Pupils remained constricted throughout patterns 1 and 2, and showed only slight dilatation during patterns 3 and 4. Only moderate dilatation occurred at deeper levels of anesthesia.

**Respiratory Signs.**—The rate and volume of breathing remained unchanged until pattern 3 appeared. At this level, upper intercostal muscle activity became depressed, and the respiratory rate became more rapid. During pattern 4 intercostal muscle activity disappeared and the respiratory rate increased to 24–32 per minute from control values of 10–16. Control of respirations was easily achieved at levels as light as pattern 1. It was necessary to assist respirations to maintain adequate ventilation during the progressive intercostal paralysis seen in patterns 3 and 4. However, assisted respirations invariably became controlled respirations at levels deeper than pattern 3. Because of this, it was difficult to determine at what level apnea would have ensued if anesthesia had been allowed to progress without assisted respirations.

**Cardiovascular Signs.**—During early phases of induction, both the systolic and diastolic blood pressure fell 10–20 mm. of Hg. This was related to the rate at which anesthesia was deepened and showed no correlation with the electroencephalographic pattern. After the induction was accomplished, the blood pressure returned to preanesthetic levels during patterns 1 through 4. During the deeper anesthetic levels of patterns 5 and 6 both the systolic and diastolic pressures remained 10–20 mm. Hg below those noted before induction. Although no irregularities of rhythm were observed, the pulse rate slowed progressively with deepening anesthesia. Maximal bradycardia occurred during patterns 4, 5, and 6. Rates of 60 per minute were common.
at these levels. A rate slower than 54 per minute was not observed in any patient. Rapid blood loss resulted in a tachycardia of 100–120 per minute even in the deeply anesthetized patient.

**Relaxation.**—Relaxation of the extremities occurred during patterns 2 to 3. Sufficient relaxation of the musculature adequate for abdominal exploration did not develop until patterns 4 to 5 appeared. Once the intestines had been packed off, however, anesthesia could be lightened to pattern 2 for the remainder of the operative procedure. It was necessary to deepen anesthesia again to pattern 4 at the termination of the operation to facilitate closure of the abdominal wall.

**Orotracheal Intubation.**—Orotracheal intubation was accomplished in all patients when pattern 4 had been established. In 14 of the 20 cases nitrous oxide-trifluoroethylvinyl ether anesthesia at this electroencephalographic level afforded adequate relaxation for laryngoscopy and intubation. In 6 patients it was necessary to give small amounts of succinylcholine to relax the masseter muscles adequately for laryngoscopy. In all cases, the endotracheal tube was well tolerated. Indeed, anesthesia could be lightened to pattern 1 without coughing.

**Anesthesia.**—Operations not requiring muscular relaxation could be performed during patterns 1 and 2 if anesthesia were lightened to this level from a previously deeper pattern. Anesthesia was profound enough during patterns 2 and 3 for intra-abdominal procedures, although it was necessary to deepen the anesthesia to patterns 4 or 5 during abdominal exploration and closure of the abdominal wall to obtain adequate relaxation.

**Discussion**

Courtin, Bickford, and Faulconer (3, 4) described seven distinct electroencephalographic levels during nitrous oxide-diethyl ether anesthesia. Their first level is identical with the first pattern of nitrous oxide-trifluoroethylvinyl ether anesthesia. During the trifluoroethylvinyl ether anesthesia, however, an additional electroencephalographic pattern is noted before high voltage slow frequency waves similar to the second level of diethyl ether anesthesia appear. Also, the spindling seen in pattern 3 with trifluoroethylvinyl ether is not mentioned in Courtin’s description of level 2 with ether. The description of third level during ether anesthesia corresponds to that seen in the fourth pattern of trifluoroethylvinyl ether anesthesia. During the fifth and sixth patterns of nitrous oxide-trifluoroethylvinyl ether anesthesia waves of long duration and slow frequency appear with faster low voltage activity in the intervals between. The electroencephalogram described for deep ether anesthesia consists of 3 to 10-second periods of cortical inactivity separated by small groups of high voltage waves.

The foregoing implies a basic difference between the electro-
enecephalogram seen with nitrous oxide-trifluoroethylvinyl ether and nitrous oxide-diethyl ether anesthesia. However, our patients were kept lightly anesthetized for long periods of time with trifluoroethylvinyl ether. It is possible because of this that we obtained prolonged recordings of a pattern that was rapidly passed through during induction with diethyl ether, as reported by Courtin, Bickford and Paulconer (4, 5).

Two factors might explain the apparent difference between nitrous oxide-trifluoroethylvinyl ether patterns 5 and 6 and the electroencephalographic levels seen with deep nitrous oxide-diethyl ether anesthesia. First, the gain of our electroencephalograph was such as to record waves of 20 μV. amplitude (4). Secondly, we never attempted to deepen anesthesia with nitrous oxide-trifluoroethylvinyl ether to a profound degree since we were able to provide optimal operating conditions for the surgeon at the levels described. It is possible, if the level of anesthesia had been deepened sufficiently, that the frequency of the large waves would have slowed to the rhythm seen in the fifth and sixth levels of nitrous oxide-diethyl ether anesthesia, and the low voltage activity between these waves would have disappeared.

In regard to character of respirations, cardiovascular stability, and the degree of painful procedure tolerated, patients seem to be more deeply anesthetized at a given electroencephalographic pattern during trifluoroethylvinyl ether anesthesia than they are with a similar pattern during diethyl ether anesthesia. Very painful operative procedures and control of respirations for open chest operations were accomplished at an anesthetic level with an electroencephalographic pattern similar to the pattern of second stage diethyl ether anesthesia. The fact that these patients were returned to this lighter pattern from a deeper level of anesthesia recalls Artusio’s experiences with diethyl ether analgesia (6). Blood pressure fall and bradycardia were complications of deeper levels of trifluoroethylvinyl ether anesthesia. There seemed to be little need, however, to anesthetize patients this deeply for more than brief intervals during abdominal exploration and closure of the abdominal wall.

Summary

Six electroencephalographic patterns during nitrous oxide-trifluoroethylvinyl ether anesthesia are presented and correlated with clinical signs. The electroencephalographic patterns during nitrous oxide-trifluoroethylvinyl ether anesthesia and those described during nitrous oxide-diethyl ether anesthesia are compared.

Trifluoroethylvinyl ether is a potent anesthetic agent. Painful operative procedures are well tolerated, and control of respirations is easily accomplished during light levels of anesthesia.
REFERENCES

5. Faulconer, A., Jr.: Correlation of Concentrations of Ether in Arterial Blood with Electroencephalographic Patterns Occurring During Ether Oxygen and During Nitrous Oxide, Oxygen, and Ether Anesthesia of Human Surgical Patients, Anesthesiology 13: 361 (July) 1952.