CHANGING CONCEPTS OF ANESTHESIA DEPTH

Carl E. Wasmuth, M.D. and Donald E. Hale, M.D.
Department of Anesthesiology

GUEDAL'S[1] description of the planes of surgical anesthesia with ether has led to the wide use of his chart in interpreting the depth of surgical anesthesia. Surgical anesthesia is, in these terms, characterized by unconsciousness, insensitivity to pain, moderate muscular relaxation and impairment of certain reflexes; indeed, loss of the eyelid, the swallowing and the vomiting reflexes is indicative of passage from the second to the third stage.[2] As new anesthetic agents have come into use, notably thiopental sodium, it has been determined that it is both dangerous and impossible to define surgical anesthesia in general in terms of the stages practical with ether.[3] Such an interpretation however is still implicit in most publications, so that many clinicians believe that an adequate anesthetic level is not obtained until the patient is totally unconscious and unresponsive to external stimuli. Such levels of "surgical anesthesia" may be dangerous; they are sometimes associated with serious cardiac arrhythmias, and circulatory and respiratory depressions.

The gas-oxygen-ether (GOE) of yesterday has largely given way to an anesthesia accomplished by the judicious combination of several agents, each of which performs its special function. It is therefore necessary to examine and to re-evaluate the planes of anesthesia and to identify their components.

The benefits of light anesthesia were described in 1914 by Crile[4] when he outlined his theory of anoci-association. If local anesthetic is used to block all painful somatic stimuli originating at the site of the surgical incision, and light cortical suppression is accomplished with another anesthetic agent, the patient is protected against the noxious peripheral and psychic stimuli associated with operation. Using the agents of his day, Crile accomplished this by combining procaine infiltration of the operative field with general anesthesia by nitrous oxide. By the judicious administration of nitrous oxide, a very light plane of anesthesia may be maintained. This has been described as the stage of analgesia.

COMPONENTS OF SURGICAL ANESTHESIA

The necessary components of surgical anesthesia are (1) *hypnosis*, (2) *analgesia*, and (3) *relaxation*. Certain undesirable side effects, such as depression of circulation and irritation of the respiratory tract, may accompany surgical anesthesia, especially if an agent such as ether is used to furnish all of the components. When different agents are combined, each of which safely provides one component, the side effects and long reaction time of deep ether anesthesia are avoided. As here described the three components are respectively provided by thiopental, nitrous oxide, and a muscle relaxant. Combinations of these agents have been used for several years; however, the point of this paper is to stress the advantages of the light anesthesia which an appropriate combination can effect. This level of anesthesia requires minimal amounts of each agent so that toxic manifestations seldom occur.

The requirements of each component of surgical anesthesia vary with the individual. For example, more sedation is required for the very apprehensive patient than for the patient who is calm. A low threshold for pain is compensated for by additional basal narcosis and/or additional quantities of the analgesic agent. If the patient is carried in the plane of analgesia from which he can be readily aroused, the incidence of arrhythmias and other abnormal circulatory and respiratory reactions is minimal.[5] The ideal general anesthesia is one that yields amnesia and surgically adequate analgesia, and requires the least amount of anesthetic agent.

In "Brain Metabolism and Cerebral Disorders," Himwich[6] describes the slow progressive depression of the neuraxis which results from the physiologic breakdown induced by insulin hypoglycemia. This slow deterioration is equivalent to a four-hour induction of anesthesia. From Himwich's observations, combined with the principles defined by Davis,[7] it appears that general anesthesias inactivate the strata of the nervous system sequentially and in the reverse order of their phylogenetic origin. "The more primitive layers may remain functionally intact while the higher layers are more or less completely depressed. Nuclei contained in the brain usually are stimulated before they are depressed by ether. Pentothal caused no excitation of the lower levels and with finely graduated doses, its action on the cortex can be outlined."[7]

(1) **Hypnosis.** Thiopental sodium is given slowly with the effect of depressing the cerebral cortex and gradually separating the patient's consciousness from his environment. Since the stage of excitement (as seen in ether anesthesia) is absent, the corresponding peripheral autonomic signs do not appear. The physiologic processes slow down to basal levels. The increased pulse rate and the hyperpnea caused by apprehension subside, and the patient becomes calm. It is important to realize however that at this point the patient can be aroused and will respond coherently to questioning. At no time is the barbiturate amnesia carried to the point of unconsciousness. Pentothal is not used to lower the threshold for pain; its principal function is to erase the memory of the procedure and of the placement of the local anesthesia in the site of the incision.

(2) **Analgesia.** Nitrous oxide is given with oxygen to provide adequate analgesia for intra-abdominal procedures. Since local injection of procaine hydrochloride provides the necessary anesthesia of the skin, the inhalation of nitrous oxide is more than sufficient to cover the pain and discomfort of manipulation in the body cavities. When pentothal provides the necessary hypnosis, nitrous oxide is administered as a smaller percentage of the inhaled mixture than if it were used alone. At the beginning of a procedure, relatively large proportions of nitrous oxide (nitrous oxide 80 per cent, oxygen 20 per cent) are usually necessary, but at all times the oxygen is maintained at 20 per cent or

PREOPERATIVE MEDICATION:

M. S. 1/8 gr. 12:30 p.m. Demerol ... mg. ... m
A. S. 1/200 gr. 12.30 p.m. Other ...

PREOPERATIVE SURVEY: Good ... Fair X Poor ...

	Yes	No	
Respiratory		X	Old Coronary
Cardiovascular	X		Infarction
C. N. S.		X	
G. I.	X		Cholelithiasis
Metabolic		X	Com. Duct Stone
G. U.		X	

ANESTHESIA COMPLICATIONS:

Yes X No ... Change anesthesia No ...

Remarks: — Period Hypotension (3-4 min.) to 80 mm. Corrected with Neo-syneph.

No. 660-904 Date Dec. 22, 1953
Name H. S.
Surgeon Dr. Hoerr
Anesthetist Dr. Wasmuth
Operation Cholecystectomy & Cholangiogram

I. V. ANES 14cc. 2 % Surital ... Pent. X
Nemb. ... Seconal ... Other ...
Induced 2:05 p.m. Completed 4:10 p m.
Total fluids 1000 cc. Total blood 1/m cc.

Age 68 years Color White Room 406
Sex Male

SPINAL ANESTHESIA: Proc. ... mg. Pont. ... mg. L. ... P. ... G. N. Catheter cm.
Level ... Remarks:

ENDOTRACHEAL: Orotracheal X Cocaine X Pent. X
Yes X No ... Nasotracheal ... Curare ... Awake X
Other ...

Methods		Spec. Procedure							
I. V.	X	Blood Venous		Pentothal	X	Metycaine		Nembutal	
INH	X	Arterial		Nitrous Oxide	X	Intracaine		Seconal	
Spinal		Cont. Hypo.		Ether		Xylocaine		Barbiturate	
C. Sp.		Cut Down		Curare	X	Cocaine	X	Nitrites	
Rectal		Plasma Expander		Vinethene		Efocaine		Aminophyllin	
Block	X	Respirator		Trilene		Morphine		Alcohol I. V.	
		EKG	X	Avertin		Demoral		Digitalis	
		EEG	X	Procaine	X	Atropine		Proc. Amide	
				Pontocaine		Scopolamine		Vasopressor	X
				Surital				Nalline	

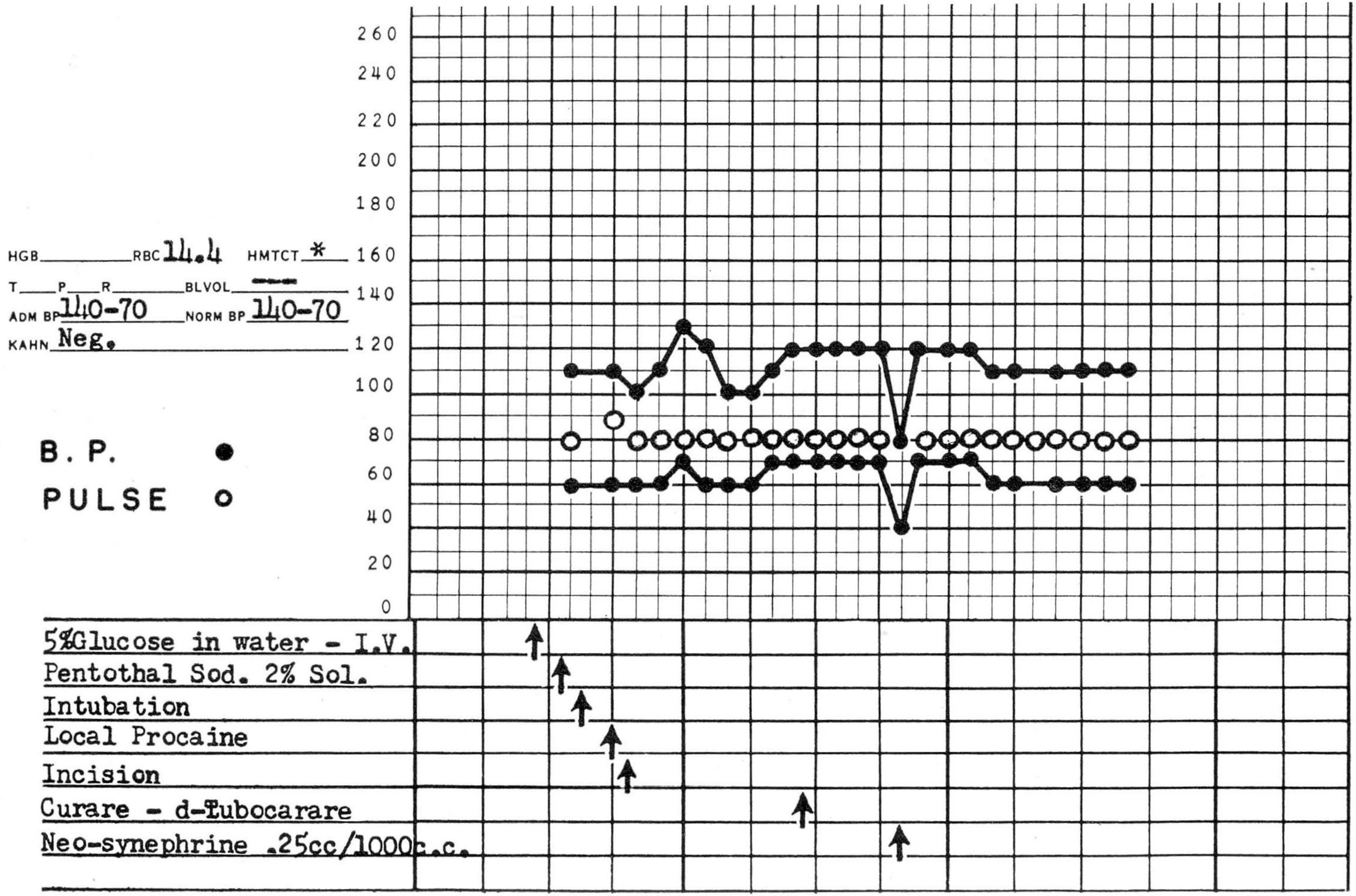

Fig. 1. Anesthesia record of the patient described in text.

above. Once the nitrous oxide has come into equilibrium with body nitrogen, the proportion can be reduced to 50 per cent: i.e., equal quantities of nitrous oxide and oxygen. This is an oxygen-rich mixture. Large flows are maintained in order to avoid the occurrence of respiratory acidosis, especially during open chest operations. Since nitrous oxide is not irritating to the pulmonary epithelium,[8] and the respiratory movements are not depressed, postoperative chest complications are not expected. The cough reflex returns soon enough after operation to prevent bronchial accumulations and postoperative atelectasis. Circulating blood and plasma volume are not affected by analgesic doses of nitrous oxide.[3] In addition to these advantages, nitrous oxide is noninflammable, inexpensive, and an excellent general analgesic. No other agent possesses all these fine qualities.

(3) **Relaxation.** Curare and curare-like substances may be given for relaxation if necessary. These muscle relaxants should be given cautiously and in small amounts. The circulatory effects of these agents should not be discounted, especially in the poor-risk surgical patient or during cardiac surgery.

TECHNIC

Premedication is morphine and atropine intramuscularly administered one hour before operation in doses adjusted to body weight. When the patient is brought to the operating room, an arm is cannulated for an intravenous drip and thiopental sodium is given through the tubing in repeated doses of 60 mg. (3 cc. of 2 per cent solution) until the patient becomes drowsy. The larynx is sprayed with cocaine (4 per cent) in an amount less than 5 cc., and the trachea is entered with a cuffed tube. The nitrous oxide-oxygen mixture is started and deep respiration is maintained by compression of the bag without re-breathing. The surgical field is prepared and procaine infiltration begun. The aim is to maintain a state in which the patient can still respond to questions by appropriately moving his head. To this end the proportion of nitrous oxide is slowly reduced and that of oxygen increased until a steady state ensues. Even at the time the surgeon is manually dilating the mitral valve or doing an esophagojejunal anastomosis through a wide thoraco-abdominal incision, the patient will nod correctly to confirm or deny suggestions made as to the color of a card held in his view. Meanwhile he is spared completely the knowledge and sensation that operation is being performed and, when questioned, will indicate that he is neither afraid nor anxious. The sensorium is so blocked that he is incapable of emotionally appreciating pain and the stage of anoci-association is reached. The physiologic aberrations of deep anesthesia do not occur.

CASE REPORT

A man, 68 years of age, was admitted to the Cleveland Clinic Hospital for removal of stones from the common duct. However, six months prior to this admission the patient had suffered a coronary occlusion. The electrocardiogram revealed signs of a posterior infarct.

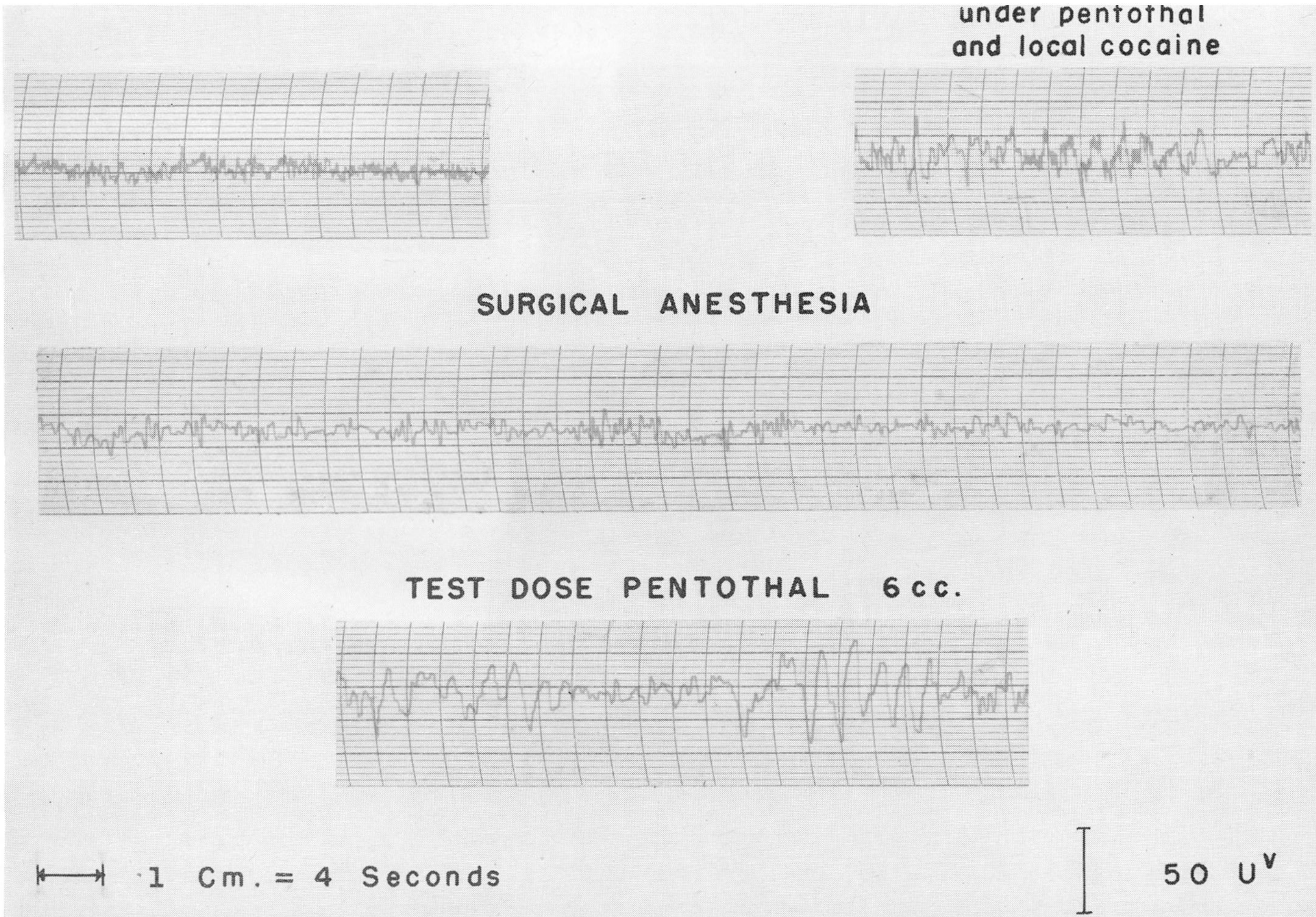

Fig. 2. Electroencephalogram during anesthesia.

Because this patient was a poor surgical risk, light anesthesia utilizing the pentothal-nitrous oxide technic was suggested. The premedication was morphine 1/6 gr. and atrophine 1/100 gr. For purposes of record, electrodes were placed in his scalp, and a preinduction electroencephalogram was taken; thiopental was given in very small amounts until the patient was asleep. Intubation was performed. Nitrous oxide was started in the 80-20 mixture. Local infiltration of the anterior abdominal wall was carried out by the surgical team and a right rectus incision was made. The patient experienced no pain during the procedure, and the pulse rate and blood pressure only momentarily fluctuated more than a few points (fig. 1). Electroencephalograms were made at various sites during the course of operation; the tracings indicate that a constant plane of anesthesia was being maintained. At the end of the procedure, a small amount of thiopental sodium was given to document the level of anesthesia by eliciting the characteristic low-frequency but high-potential waves of pentothal "excitement." The patient was soon restored to consciousness but he was not aware that the operative procedure had been performed. The endotracheal tube was removed and the patient complained of slight abdominal pain. The postoperative course in the recovery room was without incident. The blood pressure of 100/70 was maintained. No postoperative complications were experienced.

DISCUSSION

The encephalographic interpretation of anesthetic levels, as originally described by Faulconer,[8] allows the anesthesiologist to document with relative accuracy the stages of anesthesia with the various agents. In the study of this type of anesthesia, the preceding case offers a typical example. Comparing this encephalogram (fig. 2) with those published by Kiersey,[9] we find that this patient was in the earliest levels of anesthesia, levels supposedly not adequate for surgery. However, with the combination of the precedingly described technic and agents, a type of anesthesia was produced which could be described as "amnalgesia" since it combines amnesia or hypnosis (predominantly produced by pentothal) and analgesia (produced by local procaine and the inhalation of nitrous oxide). While the patient can be roused by questioning, manipulations of the viscera do not disturb him. At least when asked whether he is experiencing pain, the answer is always in the negative. Perhaps the cortical depression of the combined anesthetic agents performs a medical prefrontal lobotomy and destroys the association of pain as something disagreeable or noxious. Nevertheless, a major operation was uneventfully performed at this level and the level itself established by change in the electroencephalogram which followed the injection of additional thiopental sodium at the end of operation. In the case described, the surgical procedure was carried out in Pattern I in the Kiersey-Faulconer classification.[9] Electroencephalographically, this stage is characterized by fast spiked waves of mixed frequency between 10 and 30 cycles per second and of amplitudes up to 75 to 80 microvolts. This pattern (fig. 2) establishes that the level of "amnalgesia" is well above surgical level of unassisted thiopental anesthesia.

The complications attributable to this type of anesthesia are minimal. Central nervous depression is largely cortical; since thalamic and hypothalamic centers are not excited, this method of anesthesia is adaptable to most types of surgery. Our experience in using it for mitral commissurotomies has been excellent. There have been no cases of cardiac arrest or serious cardiac arrhythmia in the more than 90 valvulotomies.[5] Experiences in other types of surgery have been similarly good. It follows our general rule that all anesthesia is kept as light as is consistent with good anesthetic principles and with surgical demands.

SUMMARY

A method of light anesthesia is described which incorporates all of the surgical requirements of safe anesthesia. Amnesia or hypnosis is supplied by minimal amounts of thiopental sodium; analgesia is produced with nitrous oxide inhalation; relaxation, if needed, is derived from the use of curare and curare-like agents.

The abnormal physiologic variations of blood pressure, pulse rate and respiration which characterize deep levels of anesthesia are not evidenced. Although they can be aroused, these patients are not conscious of the surgical procedures being performed on them and are not suffering any pain.

The technic is exemplified by a case report and electroencephalographic evidence that a major operation can be done at a stage of light anesthesia which corresponds to Pattern I of the Kiersey-Faulconer chart.

References

1. Guedal, A. E.: Inhalation Anesthesia, ed. 2. New York, The MacMillan Co., 1951, p. 36.
2. Lundy, J. S.: Clinical Anesthesia. Philadelphia, W. B. Saunders Co., 1946, p. 346.
3. Adriani, J.: Pharmacology of Anesthetic Drugs. Springfield, Illinois, Charles C Thomas Co., 1952, p. 23.
4. Crile, G. W. and Lower, W. E.: Anoci-Association. Philadelphia, W. B. Saunders Co., 1914, p. 252.
5. Wasmuth, C. E.: Anesthesia for mitral commissurotomy. Cleveland Clin. Quart. **20**: 346-352 (April) 1953.
6. Himwich, H. E.: Brain Metabolism and Cerebral Disorders. Baltimore, Williams & Wilkins Co., 1951, p. 264.
7. Davis, N.: Phylogenetic planes in anesthesia. Anesthesiology **14**:299-302 (May) 1953.
8. Faulconer, A., Pender, J. W. and Bickford, R. G.: Influence of partial pressure of nitrous oxide on depth of anesthesia and electro-encephalogram in man. Anesthesiology **10**:601-609 (Sept.) 1949.
9. Kiersey, D. K., Bickford, R. G., and Faulconer, A., Jr.: Electro-encephalographic patterns produced by thiopental sodium during surgical operations: description and classification. Brit. J. Anaesth. **23**:141-152 (July) 1951.