ANESTHESIA FOR NEUROSURGERY *

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THE problems of providing satisfactory anesthesia for neurosurgical operations are more involved and more exacting than those pertaining to most other types of surgery. An analysis of the peculiarities pertaining to neurosurgery and the consequent demands on the anesthesiologist may help in evaluating the various methods and agents which may be selected (1, 2, 3).

(1) *Damage to Vegetative Centers.*—The intracranial lesion itself, associated increased intracranial pressure or the trauma incident to the operation may result in damage to the vegetative nervous centers with consequent circulatory or respiratory depression. Moreover, any damage which may be present can render these centers more susceptible to other insults such as hypoxia which may be incident to anesthesia.

These considerations suggest certain objectives in the administration of anesthetic agents. An effort should be made to avoid agents which will cause undue depression of vital centers. It is equally important to avoid the production of cerebral anoxia either by exclusion of oxygen from the inhaled atmosphere or by permitting respiratory depression or obstruction to interfere with respiratory exchange. To avoid increased intracranial pressure, efforts should be made to eliminate causes of coughing, vomiting and straining. A smooth induction is desirable. If there is already increased intracranial pressure, it is thought by many neurosurgeons that the use of morphine as a preanesthetic agent should be avoided. An impaired respiratory center may be overdepressed by morphine. There is also some evidence that morphine increases intracranial pressure. Since respirations may cease owing to damage to the respiratory center during the operation, provision for efficient artificial respiration should be made.

(2) *Danger of Postoperative Hemorrhage.*—Postoperative hemorrhage can prove a very serious complication. The anesthesiologist has a responsibility in the prophylaxis of this condition. One great danger is that the wound will be closed while the blood pressure is

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below normal and that severed blood vessels from which there may be subsequent bleeding may not be discovered and ligated. The anesthesiologist should keep the surgeon informed if there is hypotension. He should avoid, as far as possible, the production of hypotension resulting from deep anesthesia or from the influence of a depressant agent. He should use anesthetic agents which do not contraindicate the administration of a vasopressor drug.

(3) *Specific Requirements for Certain Neurosurgical Procedures.*—Operations which involve electro-encephalography or cortical localization by electrical stimulation require that the cerebral cortex should not be so depressed by the anesthetic agent as to obliterate the brain waves or abolish responsiveness to electrical stimulation.

(4) *Postoperative Depression.*—Damage to the central nervous system may cause prolonged postoperative coma and absence of normal reflexes. Rapid recovery from anesthesia is desirable in order that any neurologic cause of coma, such as intracranial hemorrrhage, may not be overlooked on the assumption that the depression is due to a long acting anesthetic. Also, since coma and absence of reflexes may persist, it is desirable that tracheobronchial toilet should be performed to remove foreign material from the respiratory tract before the patient is returned to the ward.

(5) *Explosion Hazard.*—Since the majority of neurosurgical procedures involve the use of cautery, X-rays or other electrical devices, it is desirable to avoid explosive agents if possible.

(6) *Field of Operation.*—For intracranial operations it is necessary that the anesthesiologist give the surgeon unobstructed access to the field of operation. This necessitates that he be able to control the anesthesia and guard the airway without encroaching on the surgeon's field. The awkward position of the head of the patient in many of these cases makes the natural airway unsatisfactory. Intubation is therefore desirable in many cases.

With the foregoing points in mind, the anesthesia requirements may be summarized as follows:

Avoid

1. Depression of respiration and circulation.
2. Hypoxia.
3. Causes of increased intracranial pressure such as coughing, straining, vomiting, respiratory obstruction.
4. Depression of cortical activity.
5. Long acting agents which will result in prolonged coma.
6. Explosive agents.

Provide for

1. Artificial respiration.
2. Tracheobronchial toilet.
3. Control of anesthesia without encroaching on operative field.

AGENTS

Local Anesthesia. The use of local anesthesia avoids depression of respiration and circulation except in the occasional case in which there may be hypotension resulting from a reaction to the local anesthetic agent. Hypoxia is not produced. The causes of increased intracranial pressure are also avoided. Cortical activity is not depressed. Postoperative unconsciousness does not result. There is no fire hazard. Should artificial respiration prove necessary, it may be difficult or impossible to achieve. Removal of material from the tracheobronchial tree is not facilitated except in so far as the cough reflex is retained. The anesthesiologist is able to keep away from the operative field only by maintaining remote contact with the patient.

Although local anesthesia is used by many neurosurgeons in a majority of their operative procedures because it avoids many of the hazards of general anesthesia, nevertheless there are disadvantages to this method which may outweigh its advantages. The experience for the patient of maintaining an uncomfortable position throughout a long and distressing operation is an ordeal to be prescribed only if means of providing oblivion are regarded as too hazardous. The possibility of toxic reactions to local anesthetic agents must not be overlooked.

Should the patient lose consciousness owing to intracranial damage there is considerable likelihood that respiratory obstruction will develop in circumstances which render it almost impossible for the anesthesiologist to insert an endotracheal tube. Similarly, should respiratory arrest occur,the anesthesiologist is seriously handicapped in his efforts to provide artificial respiration.

During these operations under local anesthesia the patient sometimes becomes unmanageable. The surgeon is then tempted to request general anesthesia. However, the administration of general anesthesia in these circumstances is unduly hazardous. The anesthesiologist is handicapped in efforts to administer an inhalation agent or to maintain the patency of the airway.

Ether. The chief advantages of ether are its potency, wide margin of safety, effectiveness in high oxygen concentration and minimal toxic effects. Respiratory depression is not an outstanding concomitant of ether anesthesia, except in the deeper planes. Circulatory depression, however, is likely to be produced, especially in elderly individuals and in those with labile vasomotor control. Hypoxia is not likely to occur except as a result of respiratory obstruction. Intracranial pressure may be increased owing to dilatation of the cerebral vessels and also because of coughing, straining, vomiting and respiratory obstruction, especially during induction. Only in deep anesthesia is cortical activity sufficiently depressed to interfere with cerebral localization or electro-encephalography. Recovery from ether is slow, especially after long operations, and marked postoperative depression must be an-

ticipated. Ether is an explosive agent and should be avoided if possible when electrical devices are used. Provision for artificial respiration can be made and the use of an endotracheal tube will provide for tracheobronchial toilet. Postanesthetic vomiting may lead to increased intracranial pressure and to pulmonary complications. The anesthetic apparatus can be so arranged that the anesthesiologist does not encroach on the surgical field.

Avertin. This agent produces marked respiratory and circulatory depression. Hypoxia may result from either of these complications. It does not cause increased intracranial pressure nor does it cause most of the complications which will lead to increased pressure, such as coughing, vomiting, and so forth. However, respiratory obstruction may occur and the insertion of an endotracheal tube may not be feasible unless the anesthesia is supplemented with another agent. Cortical activity is somewhat depressed. The narcosis is likely to persist for hours after the conclusion of the operation. No explosion hazard is involved. Provision for artificial respiration may be difficult unless an endotracheal tube is used, and this may require additional anesthesia. Similarly, the removal of foreign material from the tracheobronchial tree is not facilitated and the prolonged depression of the cough reflex may lead to pulmonary complications. The anesthesiologist may find it difficult to avoid encroaching on the surgical field unless an endotracheal tube is used. Avertin has the additional disadvantage that the dosage must be estimated beforehand, and this may result in either inadequate anesthesia or too profound depression. Some of the disadvantages of large doses of avertin can be avoided by the use of supplemental agents, such as nitrous oxide or local anesthetics, but prolonged narcosis and circulatory and respiratory depression are still likely to occur.

Cyclopropane. Cyclopropane is a potent agent capable of producing a rapid, smooth induction with a high concentration of oxygen. Respiratory depression is moderate and circulatory depression uncommon. Hypoxia is not likely to be produced. Intracranial pressure may be increased slightly but the complications which aggravate this condition can usually be avoided. Cortical activity may be depressed. Recovery is rapid and prolonged depression unlikely. Cyclopropane is explosive and should be avoided when electrical devices are used. Means of artificial respiration are necessarily present during the administration of cyclopropane and, since an endotracheal tube can readily be used, aspiration of material from the tracheobronchial tree is facilitated. The anesthesiologist can readily arrange to avoid encroaching on the surgical field.

Pentothal Sodium. This agent can produce prompt induction without excitement. Depression of respiration and circulation may be serious if deep anesthesia is produced. Hypoxia may result from these but, if oxygen is administered and deep anesthesia is avoided, there

need be no impairment of oxygenation. Pentothal tends to decrease intracranial pressure and avoids most of the complications which aggravate this condition. There is an increased tendency to laryngospasm with consequent straining and hypoxia. In moderate doses cortical activity is not seriously depressed. If used alone over a long period this drug may produce prolonged postanesthetic depression. There is no explosion hazard. Facilities for artificial respiration and removal of material from the tracheobronchial tree are not readily provided unless supplementary anesthesia is used, because intubation under pentothal alone may lead to serious straining. Although the drug is administered by vein, the necessity for the anesthesiologist to gain access to the upper respiratory tract may make it difficult for him to keep away from the surgical field.

Nitrous Oxide. Nitrous oxide is nontoxic and causes no respiratory or circulatory depression. Since it is lacking in potency it may be impossible to produce adequate anesthesia without reducing the oxygen concentration to a point which will result in serious hypoxia. Intracranial pressure may be increased owing to straining in light anesthesia or as a result of hypoxia. Cortical activity is not seriously depressed. Recovery is prompt. There is no explosion hazard. Since the administration of nitrous oxide usually involves the use of a bag and mask, artificial respiration can readily be administered. However, it may be difficult to keep a mask on the patient's face during certain neurosurgical operations and the tendency for the anesthesiologist to encroach on the surgical field may be serious. Since an endotracheal tube is not likely to be tolerated at the depth of anesthesia produced by nitrous oxide, respiratory obstruction may be troublesome and provision for aspiration of material in the tracheobronchial tree is not assured. With the exception of certain minor operations, neurosurgical procedures are usually not suitable for nitrous oxide anesthesia unless a supplementary agent is used. While ether, avertin, and morphine may be used for this purpose, pentothal has been found to offer advantages over these.

Nitrous Oxide-Pentothal Combination. By using a combination of nitrous oxide and pentothal the objectionable features of each can be avoided. Depression of respiration and circulation are minimized because nitrous oxide produces little depression and the amount of pentothal required is so reduced that its depressant effect is slight. On the other hand, the chief disadvantages of nitrous oxide, namely, lack of potency and danger of hypoxia, are eliminated because the slight amount of pentothal used contributes sufficient additional anesthesia while permitting the administration of adequate oxygen. Increased intracranial pressure is not likely to be produced by this combination because the drugs themselves do not produce it and most of the incidental complications leading to increased pressure, such as excitement, straining and vomiting, are avoided. Coughing, laryngospasm and re-

spiratory obstruction can be prevented by the use of topical anesthesia and intubation. Cortical activity is not seriously depressed. Recovery from nitrous oxide is characteristically rapid, and since the amount of pentothal is reduced to a minimum, there is little tendency to postanesthetic depression. Both agents are nonexplosive and therefore the use of electrical devices is not hazardous. An endotracheal tube inserted under topical anesthesia will facilitate artificial respiration, removal of secretions from the tracheobronchial tree and control of the anesthesia without encroachment on the operative field.

TECHNICS

To conform to the requirements enumerated earlier, certain methods of administration are of fundamental importance. The provision of an assured free airway, such as can be accomplished only by the insertion of an endotracheal tube, is essential for a number of reasons. It avoids respiratory obstruction which may cause straining and hypoxia, both of which lead to increased intracranial pressure and may even prove fatal. It facilitates artificial respiration should that be necessary. It provides a means of aspirating foreign material from the tracheobronchial tree. It provides a means of administering inhalation agents without encroaching on the operative field. To maintain inhalation anesthesia with a bag and mask or by an open technic is often difficult or impossible.

Coughing and straining may be initiated by the insertion of an endotracheal tube. These complications must be avoided either by the production of deep anesthesia before intubation or preferably by the application of a topical anesthetic to the respiratory tract. Although many neurosurgical operations last for several hours, experience has shown that the presence of a Magill endotracheal tube carefully inserted does not lead to significant postoperative sequelae.

With the provision of endotracheal anesthesia the actual technic of administration of inhalation agents and oxygen can be adapted to the needs of the situation.

Nitrous Oxide-Pentothal Administration. The following is a description of a technic of pentothal-nitrous oxide anesthesia which has been found to meet most of the requirements enumerated.

For preliminary medication, morphine and atropine are most commonly used. Atropine is given in fairly large doses but morphine is administered in moderate doses gauged according to the characteristics of the individual. The premedication is given either subcutaneously one and one-half hours before the start of anesthesia or intravenously fifteen to twenty minutes preceding induction. In those instances in which the patient is depressed or in which there is increased intracranial pressure, morphine is usually omitted. Before general anesthesia is started, the nose, mouth, pharynx, larynx and trachea are sprayed with a topical anesthetic agent such as a 10 per cent solution

of cocaine hydrochloride. Pentothal, 0.5 per cent, is started intravenously. Only a very slow drip sufficient to keep the needle open is allowed to flow at first. Nitrous oxide and oxygen are then administered in order to achieve the maximum effect of nitrous oxide anesthesia obtainable without the production of the slightest hypoxia. When this effect has been achieved the flow of pentothal is increased until adequate anesthesia necessary for intubation is produced. If the nitrous oxide were not administered prior to the increased flow of pentothal, the respiratory depression caused by the latter would greatly retard the exchange of gases necessary to obtain the maximum nitrous oxide effect. The endotracheal tube is inserted either under direct vision or by the blind nasal technic and the administration of nitrous oxide and oxygen is continued through this airway. The flask containing the 0.5 per cent pentothal is removed and a flask containing 0.2 per cent is substituted. The administration of pentothal is then continued slowly throughout the operative period, the rate being increased only when nitrous oxide proves incapable of maintaining the proper plane of anesthesia without the production of hypoxia. At the completion of the operation the anesthetic drugs are discontinued; recovery is rapid and reflexes usually return promptly. Any foreign material that is present in the tracheobronchial tree is aspirated through the endotracheal tube which is then removed.

Advantages of Nitrous Oxide-Pentothal Anesthesia. The continuous drip of a dilute pentothal solution as described by Lenowitz et al. (4) and by Stevens (5) prevents plugging of needles and allows for careful adjustment of dosage. With the 0.2 per cent solution, 30 drops per minute will approximate 0.25 Gm. of pentothal per hour. Postoperative depression is infrequent because much of the anesthesia is contributed by the nitrous oxide and the small amount of pentothal required is quickly detoxified. Many patients are awake before leaving the operating room and the majority of the remainder are awake soon after. Postoperative observations reveal a low incidence of nausea and vomiting, a very desirable feature for neurosurgical cases. Anesthesia in the upper planes is easily maintained. Even with the dilute solutions it is relatively simple to produce any desired depth of anesthesia within a short time. Infiltration of the operative site with procaine is unnecessary, and when it is tried, the amount of pentothal used for the entire surgical procedure is not markedly reduced. The dilute solutions used will not harm the tissues if inadvertent infiltration occurs. The solutions can be kept as long as ten days providing sterile precautions are observed.

Disadvantages of Nitrous Oxide-Pentothal Anesthesia. Laryngospasm may occur if topical anesthesia is inadequate. The use of a topical anesthetic agent may result in a toxic reaction. This procedure should not be started without a careful check of the history. Undue haste in the administration of the topical anesthetic should be

avoided and the slightest manifestation of a reaction should be regarded seriously.

Easily accessible veins are desirable but if not available a cut-down can be performed. The pentothal is usually dissolved in physiologic saline solution and this may result in an increased intake of sodium chloride since a separate saline solution is usually given simultaneously, to be followed by blood, if necessary. This can be circumvented by adding the pentothal to 5 per cent dextrose in distilled water. Precautions against using an excess of dextrose in diabetic patients should be observed. One must insure that the flasks are properly labeled since the dilute pentothal solutions appear similar in color to saline and dextrose solutions and might be given by mistake. The rate of flow of pentothal must be checked frequently since movement of an arm or changes in circulation may alter the rate with resultant changes in depth of anesthesia. If coughing occurs it may be the result of irritation from the endotracheal tube, especially if the head is being moved. Spraying a small amount of 10 per cent cocaine solution into the endotracheal tube will usually stop coughing.

ANALYSIS OF RESULTS

During the period in which this study was made 203 neurosurgical patients were anesthetized and of these, 126 were done by the nitrous oxide-pentothal technic described. The age range was from 11 to 71 years. The dosage of pentothal ranged from 200 mg. to 3,000 mg. The average dosage was 1,100 mg. The average duration of the procedure was 130 minutes. The range of anesthesia time was from one quarter to five and one quarter hours. Of the 124 intubations performed, 58 were nasal and 66 were oral. It was apparent that the largest proportion of the pentothal was given during the first hour. Forty-eight patients whose anesthesia time averaged sixty-nine minutes required an average dose of 845 mg., whereas 64 patients whose anesthesia time averaged 178 minutes required an average of only 1,311 mg.

Respiration and circulation were usually well maintained. In some cases a fall in blood pressure was attributed to hemorrhage. Frequently there was a slight fall in blood pressure following induction. On two occasions severe hypotension developed after the patients were placed in the sitting position.

The other 77 patients were anesthetized with the following agents: pentothal by drip alone, 5; pentothal 3.33 per cent by syringe, 40; ether, 22; avertin and local, 2; cyclopropane, 3; seconal per rectum, 2; pontocaine (spinal), 3. Intubations were performed in 28 cases, of which 15 were nasal and 13 were oral.

Ether was used mainly for children, usually by the open drop method. In these cases it was deemed preferable to use this agent despite the explosion hazard. It is generally stated that pentothal anesthesia is less satisfactory for children.

The cases in which cyclopropane was employed involved operations on the neck without the use of electrical devices.

Troublesome coughing occurred in two instances during nitrous oxide-pentothal anesthesia, in one instance during anesthesia with pentothal alone, and in a fourth case during ether anesthesia. Laryngospasm occurred in 2 cases immediately following removal of the endotracheal tube. One of these patients was anesthetized with nitrous oxide and pentothal and the other was anesthetized with pentothal alone.

Postoperative Complications

In 203 cases there were 34 (16.7 per cent) postoperative complications. For the first group of 126 cases there were 21 (16.6 per cent) complications and for the second group of 77 cases there were 13 (16.8 per cent) complications. One must bear in mind that it may be difficult to distinguish between complications which result from the operative procedure and those which result from the anesthesia. Sore throats were especially prevalent following arteriography and cerebellar procedures. In the first group of 126 cases the following postoperative complications were noted: sore throat 3, nausea and vomiting 7, atelectasis 1, shock 1, cough 3, excitement 2, urinary retention 2, edema of the larynx 1, abdominal distention 1.

In the second group of 77 cases, the complications were: sore throat 4, nausea and vomiting 3, atelectasis 1, shock 2 and cough 1. Two deaths occurred which were not attributable to anesthesia, but were the result of the neurologic disease.

Conclusions

From the standpoint of the anesthesiologist, neurosurgery presents a group of peculiar and challenging problems. These can be solved only by consideration of the group as a whole, since a solution which meets one requirement may be contraindicated by another. Ideally, we should find a solution common to all these problems but practically this has never been achieved. We are forced to compromise and to accept the solution which most nearly meets all the requirements. The method of nitrous oxide-pentothal anesthesia with intubation facilitated by topical anesthesia has proved satisfactory in a considerable number of cases. It is not implied that this method solves all the difficulties nor that other methods may not offer equal advantages (6, 7, 8, 9, 10, 11, 12). As in all operations, mutual respect, understanding and cooperation between the surgeon and anesthesiologist are prime factors in the attainment of satisfactory results.

Summary

The anesthesia problems involved in neurosurgery are analyzed and a number of requirements outlined. The characteristics of the

common anesthetic agents as they pertain to these requirements are discussed. Technical requirements are also considered. A method of anesthesia with nitrous oxide supplemented with dilute pentothal solution by drip and involving intubation facilitated by topical anesthesia is described. A series of 203 neurosurgical cases is analyzed.

REFERENCES

1. McCarthy, K. C., and McKesson, E. I.: Nitrous Oxide-Oxygen Anesthesia in Brain Surgery, Anesth. & Analg. **13**: 95–98 (May–June) 1934.
2. Stubbs, D. H.: Anesthesia in Neurosurgery, South. M. J. **34**: 1051–1057 (Oct.) 1941.
3. Hewer, C. L.: Recent Advances in Anesthesia and Analgesia, ed. 5, Philadelphia, The Blakiston Co., 1946, p. 221.
4. Lenowitz, H.; Lipson, H. I., and Stevens, E. J.: Pentothal Sodium, High Dilution for Sedation, Narcosis and Anesthesia, Anesth. & Analg. **23**: 78–81 (Mar.–Apr.) 1944.
5. Stevens, E. J.: Pentothal Sodium; Use in Continuous Intravenous Anesthesia and Method of Preserving It in Solution, Anesthesiology **6**: 376–380 (July) 1945.
6. Dandy, W. E.: Avertin Anesthesia in Neurologic Surgery, J. A. M. A. **96**: 1860–1862, 1931.
7. Wood, D.: Survey of The Anesthesias Given in 550 Brain Operations in the Years 1921–30 Incl., Anesth. & Analg. **11**: 201–205 (Sept.–Oct.) 1932.
8. Gillespie, N. A.: Endotracheal Nitrous Oxide-Oxygen-Ether Anesthesia in Neurological Surgery, Anesth. & Analg. **14**: 225–229 (Sept.–Oct.) 1935.
9. Rossier, J., and Van Wagenen, W. P.: The Use of Avertin in Neurosurgery, Ann. Surg. **103**: 535–553 (Apr.) 1936.
10. Gardner, W. J.: Encephalography, Cleveland Clin. Quart. **7**: 174–177 (July) 1940.
11. Shannon, E. W., and Gardner, W. J.: Pentothal Sodium Anesthesia in Neurologic Surgery, New England J. Med. **234**: 15–16 (Jan.) 1946.
12. Durshorwe, C. J.: Anesthesia in Neurosurgery, Anesth. & Analg. **21**: 61–74 (Mar.–Apr.) 1942.