THE BENEFITS AND HAZARDS OF PENTOTHAL ANESTHESIA * †

KENNETH M. HEARD, M.D., D.A.
Toronto, Canada

PENTOTHAL will this year celebrate its tenth birthday. Like any husky ten-year-old, it requires careful handling. Methods suited to earlier years are not necessarily the best at the present stage of development, nor is it likely that today's ideas will survive unchallenged. It is with these changing methods to meet changing times that this paper deals. It is based on the administration of pentothal, alone or in combination with other agents, to more than 8500 patients, since 1935, in St. Michael's Hospital, Toronto. It includes the work of six staff anesthetists and nine generations of interns of varying degrees of skill. If we appear dogmatic in some statements, it is because we have seen all manner of errors made with the drug and have developed certain methods which, if properly applied, will minimize the possibility of their recurrence. If we express undue enthusiasm for pentothal, it is because in our experience it has, in its proper field, caused fewer complications than other agents. No anesthetic is entirely safe. As long as people must undergo surgery, they will be subjected to inevitable risks. The advantages of pentothal are actually great enough to commend it to many who have retained an unwarranted degree of skepticism as to its merits.

What exactly is the role of pentothal in the entire anesthetic picture —a complete anesthetic in its own right or an adjuvant to inhalation and regional agents? The answer is, of course, "both." The early success of pentothal was based on its use as a complete anesthetic. More recently its field has been greatly widened and new supporters have been gained by its use in combination with gas, spinal and local. It is in this direction that future expansion seems to lie. Each method is complementary to the other. The original workers thoroughly explored the possibilities of pentothal as a complete anesthetic in all suitable fields, eliminating some types of work and concentrating on others, until each man was convinced that he had reached the limitations of the drug. Then, because in these suitable cases the results were so pleasing to the patient and satisfactory to the surgeon, he sought new uses by changes in technic. Soon the single dose, based on body weight, was replaced by continuous administration through an indwelling needle, for which purpose various mechanical aids were devised. Then the

* From the Department of Anesthesia, St. Michael's Hospital, Toronto, Ontario, and the Department of Anesthesia, Faculty of Medicine, University of Toronto.

† Presented at a meeting of the New England Society of Anesthesiology in Boston, Massachusetts, April 11, 1944.

strength of the solution was gradually weakened, allowing a more uniform injection over a longer period. Now, pentothal is being called upon to assist and modernize the relatively weak gases and the, at times, uncomfortable regional anesthetics—the so-called "combined anesthesia." Its rapid increase in popularity in recent years can be traced directly to this transition. The man who hesitated to use pentothal by itself has been using it in combination with his old favorites and finding it so useful that he is, at last, giving it a chance in its original field of complete anesthesia. Thus, more and more patients are getting the benefit of the drug in one form or another and it matters not by which road the anesthetist has traveled to conversion.

This has, however, led to considerable confusion, inasmuch as many workers have neglected to state clearly that the results apparently credited to pentothal are, in reality, due to a combination of pentothal and some other agent. The danger lies in the fact that the unwary reader may try to duplicate these results with pentothal alone, with disastrous effects on his patient or his reputation. For instance, to speak of a thyroidectomy as being done with pentothal, when actually the pentothal is assisted by a 50 per cent mixture of nitrous oxide and oxygen, is more than mere misrepresentation of the drug's potency or the anesthetist's skill—it is a downright menace to the life of the first patient upon whom it is tried by some innocent disciple who has been misled by the failure of the original report to stress the combination of agents. The responsibility for death in such a case must rest on the worker who allows a false impression to arise concerning the part played by each drug in combined anesthesia. There is no place for the man who reports half truths. If he is not prepared to explain fully and freely all parts of his procedure, then let him say nothing whatever about his work. No one should be lured into trying another man's technic without the benefit of the full experience of the originator. Let us, therefore, be more cautious in our nomenclature and reserve the term "pentothal anesthesia" only for pentothal by itself. Let us, without apology, speak of "combined pentothal" when pentothal lends its aid to, or is assisted by, nitrous oxide, cyclopropane, spinal, local or regional block.

It is not a question of what CAN be done with pentothal, but what SHOULD be done. What then are the contraindications? An analysis of even a few dozen papers would indicate probably the inclusion of almost every conceivable condition. This is, perhaps, because of the mixed audience to which a writer directs his precautions. One of the pitfalls of pentothal is its seeming simplicity. It sounds so easy that many, with relatively immature anesthetic judgment, may be tempted to try it in cases and operations for which it is not ideal—conditions from which, however, a man more experienced in meeting the emergencies of an unconscious patient might emerge safely. The limitations of any anesthetic can not be set by a list of operations which are arbi-

trarily declared "out of bounds." It is not the name of an operation which constitutes a contraindication; it is the manner in which the operation is carried out by that particular group of workers—the experience of the anesthetist with alternative agents, his ability to cope with the unexpected, the type of apparatus available, the provision of emergency equipment, the speed of the surgeon, the operative technic, the depth of relaxation demanded, the degree of cooperation shown, the skill of the assistant, the training of the nurses and attendants, and the facilities for care during recovery. Into this complex situation must then be fitted the patient. Only by consideration of all features of the resultant picture can the anesthetic be properly selected. A case in point is the insertion of Smith-Petersen nails. During the past three years, in operations on hips 52 per cent have been pinned under pentothal alone. Under our working conditions, it has proved ideal; yet in three other allied university hospitals, it is not used at all for this purpose. Therefore, it is both uncharitable and foolish to say that such and such an operation cannot be done with pentothal. Instead, the anesthetist should say, "It cannot be done with the circumstances under which I work."

There is, however, one definite contraindication which transcends all others. It must be the final arbiter in every case in which pentothal is being considered. It is: inability to maintain a clear airway, whether that inability arises from the physical condition of the patient, the site of operation or failure of the anesthetist to realize that, actually, he is not succeeding in keeping the air passages open. In any anesthetic, one of the best measuring rods of the anesthetist is the degree of oxygenation of his patient. For the man who does not rate highly by this standard, there are safer anesthetics than pentothal. In the presence of proper oxygenation—and this proviso is of the utmost importance—few physical conditions are absolute contraindications.

Damage to the liver would seem to be one danger signal, since it is apparently accepted that pentothal is broken down, at least to a certain degree, in that organ. Clinically, we have not found that to be the case. One of our common methods in operations on the gallbladder is combined pentothal and spinal. The usual dose is 0.5 to 0.75 Gm. over a period of about one and one-half hours. We have seen no postoperative complications which appeared attributable to the pentothal, even in deeply jaundiced patients. On the contrary, results have been so good that we sometimes struggle with this rather difficult technic when it would be simpler to combine the spinal with cyclopropane or use intratracheal ether throughout. Nor have we seen any harm follow the use of complete pentothal, for procedures within its recognized field, in patients with obvious liver damage. The same has been found true in cases of renal insufficiency, although this is not so unexpected since the by-products of the breakdown in the liver are conceded to have no particular effect on the kidney. In urology, where most patients have

definitely impaired kidney function, spinal still remains the anesthesia of choice, but, for those who must be denied spinal, pentothal is used almost exclusively; ether is never employed and cyclopropane only very rarely. Included in the 700 urologic cases handled with complete pentothal have been suprapubic drainage, suprapubic prostatectomy, transurethral resection, perineal drainage for infection or extravasation, dilatation of stricture, cystoscopy for biopsy or fulguration of tumor, removal of ureteral calculus, pyelography, etc. Many of these patients have been extremely ill. It is not, however, the toxic state of the patient which restricts the use of pentothal in cystoscopic procedures as much as it is the difficulty in maintaining the necessary relaxation for a period which often exceeds that originally planned. In the past three years, 14 per cent of transurethral resections and 39 per cent of suprapubic cystotomies have been done with pentothal alone. Relaxation was by no means always satisfactory but there appeared to be no accentuation of kidney damage. Advanced kidney changes are also frequently present in elderly patients who must be anesthetized, without adequate preparation, for the setting of fractures. In the past 7 years, 90 per cent of our cases of Colles fractures have been reduced with pentothal alone, with only 1 major complication—lobar pneumonia in a woman aged 78, with marked fibrillation and systolic pressure of 200 mm., anesthetized immediately on admission, against the advice of the staff. Fractured hips present a more difficult problem; almost all such patients have advanced vascular, cerebral or renal changes. In the past three years, 51 hips have been pinned with pentothal alone, although the combination with nitrous oxide is also readily adaptable to this operation. An even worse situation is found in amputation of the leg for senile or diabetic gangrene. Spinal has now been almost entirely superseded by cyclopropane, pentothal or pentothal and nitrous oxide combined. It is significant that we have been unable to introduce refrigeration anesthesia because of the surgeons' satisfaction with pentothal.

These general statements—which will not appeal to the scientist—apply to pentothal properly administered, without obstruction to the airway. If anoxemia is allowed to persist for any reason, damage to the liver, kidney, brain or myocardium may be just as great as with other agents which may have a more specific toxicity for these organs. The drug should never be held responsible for the mistakes of the administrator, nor the errors of the surgeon. In an attempt to appraise pentothal itself, blood chemical determinations were undertaken in 25 patients in good condition, who received average doses without administrative difficulty, for standard operations, without shock or surgical accident. There was no significant change in the value for the blood sugar. The van den Bergh test showed no evidence of liver damage. No albuminuria developed. The urea nitrogen content of the blood remained within normal limits.

These figures are some slight laboratory confirmation of what we look upon as a clinical fact—that pentothal is a relatively harmless drug. It is always possible, however, that the dose necessary for the operation in hand may exceed the metabolic reserve of the patient, with undesirable or dangerous effects. Five such cases have been encountered. Three were merely slow recovery, presumably because of inability of the liver to cope with the dose to which it was subjected:

(1) A man, aged 20, received 2.5 Gm. (50 cc. of 5 per cent solution) in one and one-half hours for the repair of a lacerated hand. He slept soundly, without depression or obstruction, for twelve hours. He was restless for another four hours before full recovery. (2) A robust workman, aged 32, received 1.9 Gm. (19 cc. of 10 per cent solution) in one and one quarter hours for the repair of tendons. At four hours he was still deeply unconscious. At twelve hours he was fully awake but nauseated and dizzy. Blood taken at fifteen hours showed normal urea nitrogen (11.5 mg. per 100 cc.). At twenty hours he walked home alone. In these cases the pentothal was continued beyond the customary time because of the completely uneventful course of the procedure. (3) A frail old lady, aged 74, received morphine, grain ¼, followed by pentothal 0.3 Gm. (3 cc. of 10 per cent solution) in twenty-five minutes for excision of thrombosed hemorrhoids. At eight hours she was still deeply asleep. At ten hours she was awake but irrational and noisy. At fifteen hours she was normal. On the fourth day she walked home. In this case the liver of old age would appear to have been unable to handle even this small dose of pentothal and morphine, a combination which we have frequently found undesirable.

Two other cases have more serious implications, although the actual part played by pentothal cannot be accurately assessed. Neither the anesthetic nor the operation presented any exceptional difficulty; neither the anesthetist nor the surgeon cared to accept more than a small share of the responsibility.

(1) A man, aged 81, in fair condition, with no gross cardiac changes, blood pressure 170 mm. systolic and 120 mm. diastolic, pulse 80, blood urea nitrogen 14 mg. per 100 cc., received 1.3 Gm. (13 cc. of 10 per cent solution) in twenty-five minutes for suprapubic cystotomy. Relaxation was fairly good but intermittent straining necessitated the large dose. He remained drowsy for one hour but could then be aroused to answer questions and take fluids. He could move around in bed but preferred to lapse into light sleep. Respirations were full and regular with no obstruction. Blood pressure gradually decreased, with rising pulse and temperature. He died in fourteen hours in a condition resembling that seen in uremia and similar toxic states. (2) A man, aged 63, in good condition, with previous hypertension but a preoperative blood pressure of 130 mm. systolic and 95 mm. diastolic, pulse 90, urea nitrogen 13.1 mg. per 100 cc., received 0.85 Gm. (8.5 cc. of 10 per cent solution) in thirty-five minutes for transurethral resection of the prostate. Relaxation was excellent and respirations unobstructed. Blood pressure rose from 130 to 200 mm., returning to 130 mm. at the end. Bleeding was more than usual but not alarming. In thirty minutes he was conscious and taking fluids, but very weak and apathetic. The pulse gradually weakened and blood pressure fell slowly to 80. Transfusion caused no improvement. He died in thirty-six hours in a drowsy toxic state.

Both of these end-results can be duplicated in any hospital, following many varieties of operations under all types of anesthesia, or on the medical wards, with no anesthetic at all. The lesson would seem to be that, while pentothal has a very wide margin of safety, it has, nevertheless, its limitations. These five cases are the only ones in which we have suspected definite metabolic changes; three of the same type, with complete recovery, have been reported to us from other hospitals. They are overwhelmingly outnumbered by similar patients who have emerged unscathed from very much worse conditions. As typical of these, might be cited:

A woman, aged 65, who received seven pentothal anesthesias in three years for fulguration of bladder tumor; a man, aged 35, who received nine pentothal anesthesias in two years for traumatic stricture; a man, aged 50, with urea nitrogen 23.5 mg. per 100 cc., who received 1.8 Gm. (37 cc. of 5 per cent solution) in one hour for transurethral resection of carcinoma of prostate and went home in six days; a man, aged 80, who received 0.9 Gm. (9 cc. of 10 per cent solution) in forty minutes for transurethral resection and went home in nine days; a woman, aged 70, who received 1 Gm. (20 cc. of 5 per cent solution) in three hours for bone graft of the leg.

From these cases a good guiding principle emerges: it is not desirable to exceed 1 Gm. in a healthy, robust individual nor 0.5 Gm. to 0.75 Gm. in an elderly, debilitated or toxic patient, even though the operation and anesthetic may be proceeding uneventfully. With these doses, recovery will usually be rapid and pleasant. With larger doses, these cardinal advantages of pentothal quite frequently will be replaced by a delayed recovery period of one-half to two hours, with danger of obstruction during respiratory depression or restlessness amounting occasionally to definite excitement. Therefore, as the end of the 1 Gm. ampule is approached, the anesthetist should take stock of his specific problem. Unless there is some definite advantage to be gained by continuing the pentothal, he would be well advised to use the final few cubic centimeters as a basal sedative to prepare the way for cyclopropane or nitrous oxide. The combination will often be more satisfactory than persistence in administration of pentothal alone. If these gases are not available or if they are unsuitable for the particular operation, he may carry on with pentothal, but with the utmost caution to prevent anoxemia or overdosage. While the normally pleasant recovery need not then be expected, the actual danger will be relatively slight.

Pentothal appears to have no harmful effect upon the heart. However, anoxemia resulting from administrative difficulties may cause serious damage to even a good heart or the gravest results in an already weakened one. If the color remains good, if there is no coughing or straining, if there is no hemorrhage or surgical insult, the pulse and blood pressure show little change. Any irregularity in pulse commencing in the course of properly administered pentothal must be regarded as a sign that the operation itself is imposing too great a burden on the heart. The operation should then be concluded as quickly as possible.

Merely changing to another agent will not save the heart, since it is not the anesthetic but the surgery which has accentuated existing myocardial damage, brought to light unsuspected weakness or precipitated a catastrophe, such as embolism. In a case of the latter, pentothal was exonerated, and further proof lent to this thesis, only at necropsy.

A woman, aged 63, with blood pressure 160 mm. systolic and 95 mm. diastolic, was given pentothal for removal of a loosened Smith-Petersen nail. For twenty minutes, light anesthesia was maintained on 0.5 Gm. (5 cc. of 10 per cent solution) with no obstruction or undue depression. The systolic pressure which had been 160, 150, 140 and 120, suddenly, without warning or apparent cause, fell to 75, with extreme irregularity of the pulse. So unusual is this with pentothal that the injection was immediately stopped. Oxygen, which had been given throughout, was continued by inhalation, without need of manual pressure. In five minutes the pulse was entirely regular and the systolic pressure was 120 mm. The operation was continued without further anesthetic, despite movement of the legs and phonation. In ten minutes the episode was repeated, the pressure falling to 95 mm., with gross irregularities of the pulse. In five minutes it was again of good quality. The patient left the table with a blood pressure 100 mm. systolic and 70 mm. diastolic, pulse 90, regular and good quality, moving voluntarily and answering questions incoherently. In fifty minutes she was dead. The pathologist—that great friend of the anesthetist—found extensive fat emboli throughout the entire lung and parts of the kidney. The heart was relatively good for the age; it had merely been the indicator of damage incidental to the operation, not to the anesthetic.

The rarity with which pulse changes have been found in the large number of poor risk patients handled with pentothal leads us to reiterate the belief that danger to the heart lies, not in the drug, but in technical errors. Our only deaths lend unfortunate confirmation to this tenet. These three patients had been for months completely incapacitated by arteriosclerotic heart disease, with ascites, edema, pulmonary congestion and intermittent coronary attacks. They had been undergoing hospital treatment for periods of one week, three months and five months, respectively, in the course of which surgical conditions arose demanding interference—a rapidly spreading carbuncle on the back of the neck, persistent bleeding from a rodent ulcer on the face, and infected teeth. Pentothal was chosen in preference to intratracheal cyclopropane or ether—the only possible alternatives in view of the site of the lesions. It was feared that coughing, straining or spasm during induction or intubation might lead to fatal anoxemia. Instead, the anoxemia resulted from inability to control the tongue during the progress of the operation. The condition of each remained relatively good for six, twenty and thirty minutes, respectively, until mechanical obstruction developed due to shifting of the mouth pack by the dentist, movement of the head by the surgeon, and partial turning of the patient with the carbuncle. The rapidity with which stoppage of the heart followed the obstruction justified the appraisal of the danger, even though the method of dealing with it may have been ill-advised.

If these unfortunate accidents are to be avoided and the good results duplicated, a definite technic must be developed. Just as nitrous oxide or cyclopropane must be administered by special apparatus, so also must pentothal if the maximum use is to be made of the drug. Simple procedures in patients in good condition can be carried out reasonably well with a 5 per cent solution in a 20 cc. syringe held in one hand, while the chin is controlled with the other. To attempt to handle in this way a poor risk patient, or to maintain prolonged anesthesia, particularly in combination with spinal or gas, is to court disaster. Certain major problems arise with sufficient frequency to justify suggestions for overcoming them.

Movement of the arm, with displacement of the needle, may occur in light anesthesia or in convulsive muscular seizures in susceptible patients. Light anesthesia results in a purposeful movement—squirming, wriggling, drawing up of legs and arms in resentment of the operation, whereas the other is best described as "twitching." It may start at the point of pain stimulus—often the needle in the vein—but in a well-developed case, there is a generalized, convulsive tightening of muscles throughout the body, particularly the extremities. It is cyclic —a violent tremor or jactitation, lasting perhaps ten seconds, followed by gradual and almost complete relaxation of somewhat longer duration, and this followed again by another contraction. The color remains good and respirations are frequently increased rather than depressed. Recovery is usually delayed and very often accompanied by struggling and excitement, particularly if the twitching has been mistaken for the movement of light anesthesia and an attempt made to abolish it by additional injections. Twitching is a nuisance, not a danger. Operating is always difficult and frequently must be abandoned or continued under inhalation anesthesia. This is, indeed, the wisest course once a patient has been found to be a twitcher, since the reaction is the result of an idiosyncrasy to the drug and will only be intensified by further dosage. Fortunately, less than 10 per cent of patients appear to be sensitive to pentothal in this way, as compared to very much larger numbers with other barbiturates. Robust, young adults are the worst offenders. Morphine preoperatively tends to diminish twitching, but may, in itself, lead to an unduly long recovery period with respiratory depression. With us, the incidence of twitching has been about the same with various dilutions—2.5 per cent, 5 per cent and 10 per cent, although with slow, even injection, we have sometimes been able to find an optimum level which gave fair relaxation. There is no method of detecting a susceptible patient in advance. When there is a history of twitching during a previous intravenous anesthetic, some other method is probably advisable.

A misplaced needle may lead to extravenous injection, with inevitable irritation and possible sloughing. Under no circumstances is it justifiable to inject pentothal unless the needle is, without question, in the

vein. We have had three cases of subcutaneous injection followed by redness, swelling and tenderness: two with 10 per cent solution and one with 5 per cent solution. We have had five cases of actual slough which healed in from four to six weeks with hard, indurated scars: four with 10 per cent solution and one with 5 per cent solution. We have had four cases of phlebitis despite the injection having been undoubtedly confined to the vein. Tenderness along the vein above the site of injection developed in five to seven days; all followed injection of 10 per cent solution: all subsided in ten to fourteen days. Until 1941, the 10 per cent solution was used exclusively; since then, nothing stronger than 5 per cent solution has been employed. We feel that the 10 per cent solution has a number of advantages from the standpoint of anesthesia obtainable, but since the danger following improper injection appears greater, it has been deemed expedient to change to the more universally accepted dilutions.

A much more frequent complication, the dangers of which have already been stressed—but by no means too strongly—is anoxemia caused either by overdosage or obstruction. Overdosage always results in respiratory depression or stoppage. It can always be dealt with provided the airway is perfectly clear; the first flicker of returning respiratory activity will then draw air directly into the lung, or in the more serious cases, oxygen may be forced in under pressure. It can be avoided, during induction, if the patient is asked to count aloud and the injection continued at the rate of 1 cc. of 5 per cent solution per ten seconds, only until the patient stops counting, after which injections of 0.5 cc. to 1 cc. are given as indicated by relaxation and depression. During the operation, overdosage is almost always the result of attempting to restore full relaxation to a patient whose anesthesia has become too light or who has developed cough, hiccup or laryngeal spasm because of failure to control the airway. Deeper anesthesia can then only be regained safely by repeated small doses, with an interval of at least thirty seconds between each 0.5 cc. to gauge the effect. Straining because of obstruction must never be met by further injections until the cause of the obstruction is removed.

Death due to simple overdosage in patients with unobstructed airways must be very rare. In the case of a debilitated woman with advanced carcinoma of the cervix receiving pentothal for the insertion of radium, the intern accidentally injected 1.5 cc. of 5 per cent solution when she was already fully relaxed and showing undesirably shallow breathing. The mishap was noticed instantly and oxygen from a gas machine started within twenty seconds. Respirations had by that time ceased and the pupils were widely dilated, with no reaction to light. The airway was clear of all obstruction and even light pressure on the bag caused obvious expansion of the chest. By rhythmic inflation, good color was maintained, the pulse rose only to 100 and the systolic pressure fell only from 120 to 105, despite recent cardiac decompensation.

After eight minutes, spontaneous respirations were resumed, gradually increasing to a good volume in fifteen minutes. Fortunately, she had received no morphine preoperatively and it was necessary to combat only the relatively short depression of the pentothal. We believe that morphine should be used only in robust, young individuals and that, in the average patient, any reduction in the amount of pentothal used does not compensate for the increased depression of the combination. So simple was the maintenance of aeration here, in the absence of obstruction, that the surgeon at no time suspected that artificial respiration was being performed. In the presence of obstruction, however, even transitory depression may result in fatal anoxemia. That has been the chain of circumstances in most of our major accidents and our three fatalities on the table.

The avoidance of obstruction is a greater problem with pentothal than with inhalation agents because, even with good relaxation, the cough and pharyngeal reflexes are seldom completely abolished. Only occasionally will an intrapharyngeal airway be tolerated; coughing and straining following its introduction will usually upset the previously good working conditions. Similarly, if the tongue slips into the wrong position during light anesthesia, it also sets up coughing or gagging. We do not think that pentothal in itself causes laryngeal spasm. We believe that the spasm frequently seen is secondary to irritation of the larynx and that the anesthetic will proceed without spasm unless such a stimulus is provided by a misplaced tongue, saliva, mucus, artificial airway, suction tip, malformed epiglottis, bronchial secretion, vomitus, etc. On theoretical grounds, atropine is used in about one quarter of cases; there has not been any convincing evidence of its benefit. Spraying with a local anesthetic might be of value; we have not used it since it is objectionable to many patients and neutralizes the otherwise pleasant induction. We prefer, instead, to concentrate on the elimination of obstruction or mechanical irritation by scrupulous attention to the jaw.

In the treatment of obstruction, oxygen is of the utmost value and no prolonged or difficult procedure should be commenced without it available for immediate use. The extension of this rule to include every pentothal anesthesia might limit the application of the drug but would certainly prevent many complications. All of the arguments in favor of the high oxygen content of cyclopropane mixtures are just as applicable to pentothal. The patient who is subjected to respiratory stoppage or obstruction after having breathed 50 per cent oxygen for some time, must be in better condition to withstand the accident than one who has been breathing only air. The most efficient method of administering oxygen is by a regular gas machine. In an emergency, it is as simple to maintain respiration by pressure on the bag as it is during cyclopropane anesthesia. If necessary, an intratracheal catheter can be passed and used, in conjunction with the regular equip-

ment. For prophylactic oxygen, the mask is usually best held away from the face, to avoid interference with control of the tongue. If intranasal catheters are preferred, they may be connected to the customary intratracheal adapter of the gas machine. They must be placed so as to deliver oxygen into the nasopharynx without stimulating the cough reflex. The same connections will also allow the use of the B.L.B. mask—probably the ideal inhaler. It causes no nasal irritation, does not interfere with holding the jaw and allows the tongue of a toothless patient to be grasped and extended through the oral opening. Even with the gross leakage of these methods, a flow of 6 or 10 liters per minute should materially enrich the inspired air. If a gas machine is being used as a source of oxygen, it is always possible to change to cyclopropane or nitrous oxide—either deliberately or from necessity—with a minimum of disturbance or delay. When one is not available, equally good results can be obtained by an oxygen therapy unit, if provision has been made for forcible administration under pressure if necessary. This need be nothing more complicated than a gas machine bag attached to an ordinary face mask; no valves are required—merely an inlet on the improvised connecting piece to admit oxygen. A standard unit may be improved by a two-way valve to bypass the water chamber and permit the delivery of dry oxygen for the B.L.B. mask or pressure bag and humidified oxygen for intranasal catheters. If mounted on a suitable carrier, it brings the safety of oxygen to the patient in any part of the hospital.

These complications can be prevented, or treated, if the anesthetist selects his cases in accordance with his familiarity with the drug and provides himself with the apparatus necessary for its use in the more difficult procedures. No anesthetist would use cyclopropane for a gastric resection, for instance, unless he had previously gained experience in minor work. Yet the same man may be tempted, by the apparent simplicity of pentothal, to try it in bronchoscopy before he has used it even for an infected finger. The wise anesthetist will serve his apprenticeship in short operations on patients in good condition. These he can handle by himself. In the more difficult situations, the assistance of a nurse is necessary to control the airway or syringe, depending on which presents the greater problem. The range of single-handed activity, however, can be greatly extended by a little ingenuity in making the injection. Some mechanical device becomes, in fact, an absolute necessity when pentothal is to be combined with spinal or gas.

The pentothal-spinal combination depends on spinal relaxation and pentothal amnesia. It requires a complete spinal anesthesia of sufficient height and duration to allow the operation to be completed successfully but not necessarily in comfort. The latter is supplied by the pentothal which must be administered continuously in minute doses—just enough to keep the patient in a drowsy, euphoric state, with a happy disregard of his surrounding. The only apparatus necessary is an ordinary con-

tinuous intravenous set-up plus a length of similar tubing and dropper connected to a solution bottle or graduated cylinder. The latter contains the very dilute solution used, 1 Gm. dissolved in 250 cc. of saline solution. The intravenous saline or glucose solution is started in the usual way, and the needle from the pentothal container inserted through the tubing near the intravenous needle. Thus the patient receives a measured amount of saline, pentothal or both. No valve, stopcock or two-way adapter is needed. To prevent back-filling from one side to the other, the needles should be of the same bore and the height of each jar should be adjustable independently. Any plane from complete sleep to full consciousness can be obtained by varying the flow of the two solutions. In the ideal case, the patient dozes if undisturbed but can answer questions intelligently, although with some drunken, slurring of speech. Euphoria is the characteristic feature, and is almost always followed by complete lack of recollection of events. From this pleasant condition he can be lowered into full sleep for short periods to cover nausea, distress from traction, etc. As soon as the need has passed, the pentothal can be reduced and he will return to the lighter level. It seems more reasonable to produce complete sleep when desired and maintain it only for the time necessary, than to attempt to cover the entire operative period by massive preliminary sedation which may be excessive most of the time and inadequate at the critical phase. For the apprehensive patient who has no objection to the puncture provided "she doesn't see anything," the combination offers the benefits of spinal and the comfort of general anesthesia. It permits the use of spinal in cholecystectomy, colostomy, resection of lower bowel, hysterectomy, etc., where the advantages of spinal relaxation are frequently foregone because of the temporary distress which may accompany certain manipulations. The only difficulties arise in cases in which full sleep must be maintained for more than fifteen minutes at a time, when the amount of pentothal required may result in restlessness and irritability upon recovery to a lighter plane. Thus, gastric resections and difficult bile-duct dissections are usually unsuitable. In renal surgery it is ideal: in the past three years 47 per cent of all open operations on the kidney or ureter have been done under this spinal-pentothal combination.

For complete pentothal anesthesia or the combination with cyclopropane or nitrous oxide, the dilution of 1 Gm. in 250 cc. of saline is inadequate; it must be delivered in higher concentration with greater rapidity. From the earliest days (1), the continuous intravenous injection has provided a simple method of preventing blockage or displacement of the needle, while full strength pentothal is injected into the tube with a syringe and fine needle. Between doses, the anesthetist is free to control the airway and administer oxygen, or in selected cases, nitrous oxide or cyclopropane. Since the pentothal reaches the blood only after being diluted and swept in by the accompanying saline solution, the action is considerably slower than when it is deposited directly in the vein

at normal strength. There is, therefore, danger that a second dose may be added before the first has had time to take effect, with cumulative overdosage. This can be prevented if, after full anesthesia has been established, subsequent injections are limited to 1 cc. of 5 per cent solution, with an interval of at least one minute between doses, despite any apparent lightness of anesthesia. If a small syringe containing not more than 1 cc. is used, the time required to reload it will provide the necessary safeguard and also prevent weakening of the solution by backflow from the intravenous drip. Both of these difficulties have been solved by a very simple syringe holder which, like the 1 in 250 technic, was developed by Dr. C. G. Bryan, Chief Anesthetist, St. Michael's Hospital. On a small board are mounted two spring clips to hold the syringe. A metal slide grips the edges of the base and is pushed along behind the plunger, effectively blocking any back pressure from the intravenous and permitting the injection of as little as 0.25 cc. at a time. To obviate the necessity of a continuous intravenous injection, the syringe, held in the hand, strapped to the patient's arm or mounted in this holder, may be connected directly to the vein by a flexible tube. Prevention of clotting then depends on a short interval between doses.

Machines have been designed to eliminate a continuous intravenous injection, while allowing each dose to be alternated with an injection of saline solution to prevent occlusion. Among the early ones were those of Jarman (2) and the author (3), both published in 1936. Such devices were primarily developed to minimize injection troubles and leave the anesthetist free to control the airway or administer oxygen. It has been a logical advance to replace the oxygen with nitrous oxide or cyclopropane when trouble arises because of obstruction, twitching, displaced needle, inadequate relaxation or prolonged operating. For this type of problem, cyclopropane is usually preferable, unless contraindicated by explosive hazard, etc. It is sufficiently strong to carry on from where the pentothal leaves off. In the transition, two-fold depression must be guarded against. Nitrous oxide, being considerably weaker than pentothal, is not likely to be the remedy for coughing or straining: its use before the relief of obstruction is certainly undesirable. The function of nitrous oxide is to assist smoothly administered pentothal—not to replace it. It will be effective only as long as appreciable pentothal action remains. When each helps the other during concurrent administration, there is neither cyanosis from nitrous oxide nor depression from pentothal; each robs the other of its chief hazard. It is truly combined anesthesia, as proved by the deterioration of working conditions if either one is reduced below the optimum level. The obvious need, then, is for a means of giving pentothal in a solution strong enough to increase relaxation instantly when needed and in doses measured with sufficient accuracy to avoid unnecessarily large amounts over a period of one to two hours.

This was, in a large measure, accomplished by the very ingenious gear-driven syringe described in 1940 by Davison and Rudder (4). The apparatus herewith presented by the author provides the accuracy of screw-controlled injection by a different principle, and incorporates original features to prevent displacement of the needle. It permits the most efficient use of the drug, either alone or in combination, while allowing the unassisted anesthetist to maintain adequate aeration or complementary inhalation anesthesia (fig. 1). It can be used with almost any

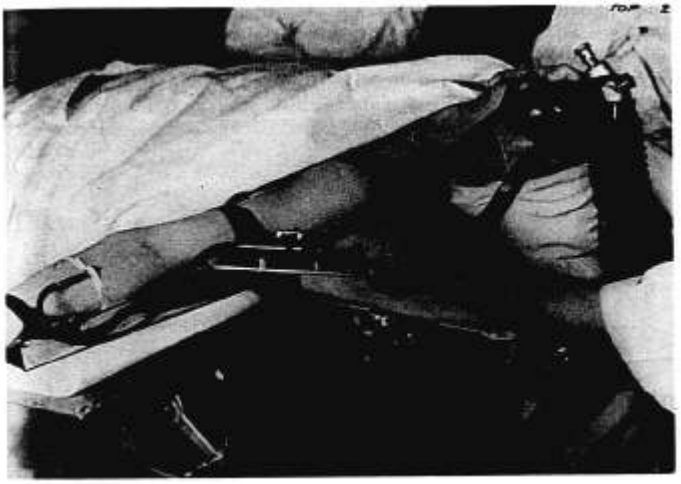

FIG. 1. Concurrent administration of pentothal and nitrous oxide, cyclopropane or oxygen.

20 cc. syringe. The mechanical drive permits the plunger to move forward for injection or backward for aspiration, to load the syringe or to prove that the needle is properly in the vein. It is instantly adjustable to either movement and can deliver, in either direction, anything from a single drop to 2 cc. It can be attached to the syringe itself and used for injection directly into the vein or it can be mounted on a holder which is an integral part of the armboard. This allows a wide range of accidental movement of the arm without interference with the injection (fig. 2).

The armboard is a metal trough 15 inches long, with adjustable straps at each end to hold the arm extended, comfortably but firmly. At each corner is a socket, into any one of which the syringe holder can be inserted by a swivel joint which allows the holder and syringe to turn

through an arc of 180°. The syringe is connected to the needle by a flexible tube and this permits the holder to be turned at any angle to the arm. By adjusting this angle and choosing the appropriate socket, any vein from the wrist to the elbow of either arm may be used, with the drive-wheel at the anesthetist's hand whether he is standing beside the patient, at the end of the armboard or at the head of the table with the gas machine. Mounting the syringe holder directly on the armboard makes the arm, needle, tubing, syringe and armboard a single unit which can be moved as a whole. Unless the forearm twists or turns beneath the retaining straps, there is relatively little likelihood of a displaced needle. The patient may be turned from side to side or pulled up and down on the table with safety. The arm may be moved in or out to accommodate the surgeon, or actually waved in the air in light anes-

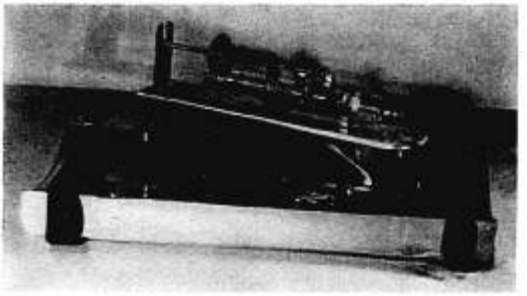

FIG. 2. Complete injection apparatus. The arm is held in the trough-shaped armboard, to which is attached the syringe holder by a swivel joint, permitting the use of any vein from the wrist to the elbow of either arm. The arm, needle, tubing, syringe and armboard are then a single unit which can be moved as a whole, without interference with injection.

thesia. Other machines are fastened rigidly to the table, not to the patient, and such movements result in pulling the patient away from the needle. The syringe is loaded with 5 per cent solution and laid in the trough-shaped holder. The separate drive-unit is clamped to the barrel by retention screws which are adjustable for different syringes. The upper clamp is permanently mounted on a threaded shaft, extending the length of the syringe and plunger. The drive-wheel moves along this fixed shaft, pushing the plunger forward at the rate of 1/32 inch per revolution. Aspiration is accomplished by a smaller wheel mounted on the threaded collar of the drive-wheel; the head of the plunger fits loosely between the two wheels, the distance being adjustable from 3/16 inch to 5/16 inch to fit almost any shape of plunger. When the drive-wheel is turned, it carries the aspirating-wheel with it—either forward to inject or backward to aspirate. Before clamping the unit on the loaded syr-

inge, the drive-wheel is spun back opposite the head of the plunger, with the two wheels widely separated to allow some play during adjustment. Further rigidity is obtained by a lock-nut which holds the collar of the barrel against the edge of the trough. The sterile connecting tube, glass observation tube and needle are connected to the syringe, air is expelled by forward movement of the wheel and venipuncture performed. If large amounts are needed quickly for induction, the drive-wheel and aspirating-wheel are left widely separated and the plunger pushed forward, with the thumb, for the available distance, ¾ inch or approximately 2 cc. The reverse maneuver permits aspiration of a similar volume, if desired. Once anesthesia is established, the wheels are approximated to grasp the head of the plunger loosely. These adjustments can easily be made with the thumb and forefinger of one hand.

The advantages of controlled injection can be obtained without the armboard if desired. An auxiliary bottom clamp permits the drive-unit to be fastened directly to any syringe which, during use, may be held in the hand (fig. 3). This may be of value in an operation commenced with

FIG. 3. The injection-unit fastened directly to any syringe for use without the armboard.

a plain syringe but which becomes unexpectedly prolonged: the unit can then be attached to the syringe while it is in use. With either method of assembly, undue pressure on the clamps or lock-nut will squeeze the barrel and cause the plunger to bind. Similar binding may interfere with aspiration, but not with injection, when the plunger is extended more than half its length; in any position, injection of any amount from one drop to 2 cc. can be made, as desired.

SUMMARY

In 8,500 pentothal administrations, three deaths and most major complications were caused by obstruction of the air passages. When the airway was properly maintained, little harm followed even large doses. In only five cases was any metabolic change suspected. However, the maximum desirable dose is approximately 1.0 Gm., and if this is exceeded, the outstanding benefits of pentothal need not be expected. The combination of pentothal with nitrous oxide, cyclopropane or spinal anesthesia is, in many cases, preferable to the use of these agents alone.

Methods by which this can be accomplished with readily available apparatus are described. For use in the more complicated procedures, there is presented a new gear-driven syringe holder which permits the most efficient use of the drug, either alone or in combination, while allowing the unassisted anesthetist to maintain adequate aeration or complementary inhalation anesthesia.

REFERENCES

1. Wright, A. D.: Technique of Evipan Anaesthesia, The Lancet 228: 1040–1041 (May 4) 1935.
2. Jarman, R.: Technique of Intravenous Anaesthesia, Lancet 230: 600 (Mar. 14) 1936.
3. Heard, K. M.: Pentothal: A New Intravenous Anaesthetic, Canad. M. A. J. 34: 628–634 (June) 1936.
4. Davison, T. C., and Rudder, F. F.: A Mechanical Device for the Administration of Intravenous Anesthetics, Am. J. Surg. 50: 323–324 (Nov.) 1940.

For the information of anesthesiologists who are contemplating application for certification by the American Board of Anesthesiology, Inc., or who are training physicians for the specialty, the following questions have been employed for Part I (written) examinations in the past in *Pharmacology:*

1. *a.* A short-acting barbiturate loses its advantages if given in large doses. What measures are commonly employed to keep the doses of barbiturates to a minimum?
   b. What are the important considerations before and during intravenous administration of pentothal sodium to a patient who is in shock? How do these considerations differ from those which apply when the patient is in average good condition and from those which apply when the patient is distinctly rugged?
2. *a.* What are some of the reasons why ether has not been very satisfactory as an agent for intravenous anesthesia?
   b. What are some of the difficulties encountered when ether in oil is used for rectal anesthesia?
3. *a.* In a case in which cyclopropane is the main anesthetic agent used, why may it be well to use ether also?
   b. In a case in which cyclopropane is the main anesthetic agent used, why may it be well to avoid the use of ether?
   c. If ether is avoided, as in (b), what other agents, given by injection or by mouth, might be used in place of ether?
   d. What is the value of "controlled respiration" (Guedel's apneic technic) when administering cyclopropane and oxygen?
4. Are these agents modified or detoxified in the body? If so, how and where? Ether, cyclopropane, chloroform, nitrous oxide, pentothal sodium, procaine.