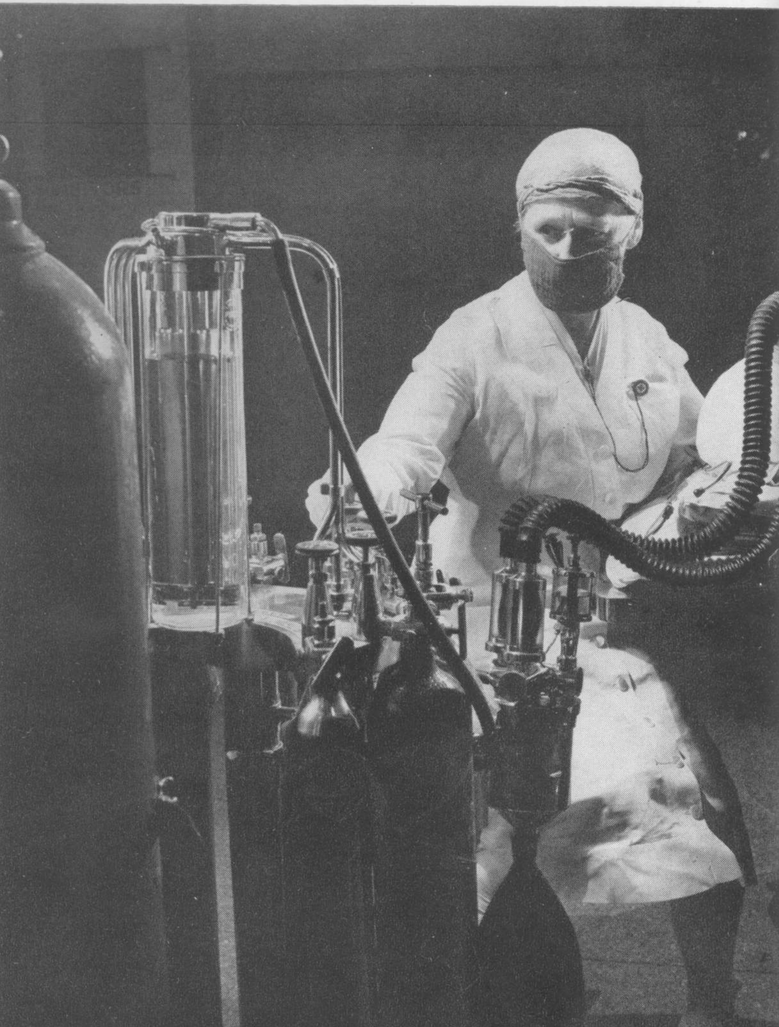
ANESTHESIA:
Principles and Practice

And last, not least, in each perplexing case,
Learn the sweet magic of a *cheerful face*;
Not always smiling, but at least serene,
When grief and anguish cloud the anxious scene.
Each look, each movement, every word and tone,
Should tell your patient you are all his own.

—DR. OLIVER WENDELL HOLMES



ANESTHESIA:

Principles and Practice

A PRESENTATION FOR THE NURSING PROFESSION BY Alice M. Hunt

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FOREWORD

It is a pleasure to have the opportunity of acknowledging the great obligation which the Surgical Department of the Yale University School of Medicine and the surgeons operating in the New Haven Hospital these past twenty-five years have owed Miss Hunt for her skill and her devotion to the welfare of the patient in the performance of her duties as a teacher and a practitioner in the field of anesthesia. It is indeed fortunate that she has had the opportunity and the desire to summarize her experience in this manner.

Whether or not the nurse will continue to have as important a role in the field of anesthesia as she has had in the recent past, it will always remain true that she, whatever her activities may be, will need to have an intelligent understanding of anesthesia, and it is to this end that this book has been written. The professional anesthetist will of course seek elsewhere for more detailed and technical information, but nowhere will the intimate concern for the welfare of the patient, which is or should be the primary motivation of physician and nurse alike, be found better expressed.

SAMUEL C. HARVEY, M.D.

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INTRODUCTION

THE preparation of this book was undertaken with the primary object of presenting to nurses in general a clear and practical concept of the subject of controllable anesthesia, which has played so vital a role in the evolution of surgery from the stage of "choice of last resort" of a century ago, and all preceding time, to the almost limitless possibilities of this momentous branch of medicine today.

It is the intention of the author that focus be concentrated on the patient, not the surgeon, as rightly being in the center of the picture—without the patient none of us would be necessary, surgeon, anesthetist, nurse, or hospital. In consequence, emphasis is given to details of procedure and nursing care to enhance the comfort and well-being of the patient, the importance of which, unfortunately, is not in general sufficiently appreciated as being a necessary adjunct to the perfection of anesthesia in each individual case. And only when the course of anesthesia is smooth and under good control can the surgeon's work proceed with complete accuracy and safety. Such efforts of living up to the ideal of the Golden Rule will also be found to pay us high dividends in personal satisfaction and the lasting gratitude of many patients to whom the fear of "taking ether" is a very real, though perhaps nowadays an irrational, dread.

Simplicity in administration of the various anesthetic drugs, and safeguards against special dangers, are detailed for the guidance of the nurse who may at some time of emergency find herself having to extemporize as anesthetist. It is hoped also that a fund of experience, gained over many years devoted to the practice and teaching of the art of anesthesia, may prove helpful to those beginning their career in this specialty.

I have had the good fortune of participating to the full in the modern evolution of surgical anesthesia. This I have found very stimulating and enjoyable. I appreciate the fact that success in the enterprise was made possible, largely, by the trust and co-operation afforded me by the many surgeons with whom I have been associated over the years. I feel especially indebted to Dr. Samuel C. Harvey, my "chief" for the last twenty-five years, under whose sympathetic and inspiring leadership I was enabled to keep our department of anesthesia up to date.

I am grateful also to Dr. Edna H. Tompkins for much valuable assistance in the compilation of this book and to Mrs. Marguerite DuMortier for her unfailing interest and encouragement in the project.

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New Haven, Connecticut

ANESTHESIA:
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Chapter 1

BRIEF HISTORICAL OUTLINE OF SURGICAL ANESTHESIA

IN keeping with our reactions to many modern inventions that have added so much to the ease and well-being of normal daily life, we tend to look upon controllable surgical anesthesia as so much a matter of course and necessity that we fail to appreciate its infinite boon and the fact that this has been available to the civilized world for only one century.

At the Massachusetts General Hospital, Boston, Massachusets, on October 16, 1846, for the first time in history a group of reputable physicians were given convincing proof that, by inhaling ether vapor, a patient could safely be made insensible to the pain of a surgical operation.

Over the ages, seemingly, pain had been considered so inevitably a part of life that had to be endured that attempts to alleviate it were sporadic and unconvincing. Primitive man resented pain as an invisible demon that could, in some unexplainable way, take possession of his body. Charms of weird variety were worn as guard against the demon's entrance or, once enthroned, he might be exorcised by fright or magical incantations.[1]

However, from time immemorial, mankind has sought palliatives to heal or soothe his pain. Probably in his search for food he early learned that many vegetable substances have hypnotic and analgesic effects when chewed, or burnt and the fumes inhaled. That this knowledge was used for the relief of pain as civilization progressed is evidenced by many references found in the literature of ancient Greece and Rome, of China, Assyria, and Egypt, and throughout the early Christian era. Notable among the substances used were henbane and the root of the mandrake—hyoscin; seed of the white poppy—opium; leaves of the coca tree—cocaine; and the fumes of burning hemp—Oriental hashish. There are many recipes for the preparation of elaborate combinations of these and other vegetable substances, which are to be imbibed or inhaled by patients prior to imperative surgical operations, such as amputation of diseased or injured limbs, trephination, removal of bladder stone, etc.

Alcoholic beverages of sorts seem to have antedated recorded history, and their hypnotic effects were noted and used for the relief of pain. But crude drugs of all kinds have many side actions, often harmful and dangerous; their general effect is unpredictable and specific effect definitely beyond control. Not until the active principle of opium—morphine—was discovered by the German chemist, Friederich W. Sertürner,[2] in 1806, could this most valuable narcotic drug be used with reasonable safety. He named the alkaloid morphium, after the Greek god of dreams, Morpheus. By his invention of the hollow needle in 1853, Dr. Alex-

[1] René Fülöp-Miller, *Triumph Over Pain*, p. 11.
[2] Thomas E. Keys, *The History of Surgical Anesthesia*, p. 38.

ander Wood of Edinburgh blazed the trail for the modern hypodermic injection of this drug.

Descriptions of surgical operations in preanesthetic days are most harrowing. For the patient to survive the agony involved, the procedure had to be completed hastily. Haste is usually the antithesis of gentleness, and probably surgeons became more or less calloused to causing pain. But the more sensitive surgeons, doubtless, suffered with the patient and understandingly sought means for controlling the pain. Among such, in the sixteenth century, was the famous German physician, Paracelsus, who, it is recorded, by combining and distilling sulphuric acid and alcohol discovered ether and named it "sweet vitriol." He most remarkably anticipated modern medical research by testing its effect on chickens, noting that it put them to sleep and they subsequently awakened unharmed.[3] He recommended that the drug be used as an anodyne, and there is evidence that it was so prescribed, more or less, through succeeding centuries, to be used in liquid form dropped on sugar or in wine.

Ether vapor seems to have been first used therapeutically about the mid eighteenth century, when a Liverpool surgeon advised it "be snuft up the nose" repeatedly for relief of persistent headache.[4] Evidently it was not intended that this be continued to the point of loss of consciousness, such being considered too hazardous a procedure.

The foundation of modern surgical anesthesia has been ascribed to the painstaking study of gases by the English chemist, Joseph Priestley. In the late eighteenth century he succeeded in isolating carbon

[3] *Ibid.*, p. 9.

[4] John F. Fulton and Madeline E. Stanton, *The Centennial of Surgical Anesthesia: An Annotated Catalogue*, p. 22.

dioxide, oxygen, and nitrous oxide and stimulated interest in the experimental use of gases in the treatment of disease.[5]

A "pneumatic institute" was established in Bristol, England, by a Dr. Beddoes and rapidly gained popularity. The famous chemist, Sir Humphrey Davy, was employed there as a very young man and became especially interested in the study of nitrous oxide. About 1800, on inhaling the gas one day he noted as a remarkable fact that the pain of an aching tooth was greatly relieved, which prompted him to make the prophetic suggestion that nitrous oxide might prove valuable for the relief of pain during surgical operations. But this prophecy was not fulfilled for nearly half a century, despite the devoted efforts of another young Englishman, Dr. Henry H. Hickman, who had scientifically confirmed Davy's hypothesis in 1820 but failed to impress the bigoted medical world of England and France. It has been well said "the time was not ripe" for the acceptance of so startling an innovation.[6]

Nitrous oxide, when inhaled diluted with sufficient air to prevent asphyxial symptoms developing, frequently initiates a state of exhilaration and intoxication, interesting and amusing to the subject and to observers. Ether vapor has a similar effect. This fact soon was noted and the practice later exploited, especially in America, by pseudo chemists as a lucrative show business, volunteers from the audience being used for subjects. Inhaling the vapors also became a popular means of entertainment among groups of medical students. During these so-called "ether frolics" subjects frequently became boisterous and active, to the added merriment of the audience. Occa-

[5] Keys, *op. cit.*, p. 14.
[6] Fülöp-Miller, *op. cit.*, p. 85.

sionally minor injuries resulted, and it was noted independently by at least two observing young men, Dr. Crawford Long of Athens, Georgia, and Dr. Horace Wells, a dentist of Hartford, Connecticut, that while under the influence of the gases the subject was quite unconscious of pain at the site of injury.[7]

These men were sufficiently impressed to experiment further with the pain-control effect of the drugs, hoping to benefit their own patients thereby. Dr. Long's results with ether were so satisfactory that he accomplished several minor surgical operations painlessly in the year 1842. But his practice was limited, and Athens, Georgia, so small a community that little publicity was given to this surprising achievement. Two years later, in 1844, the Hartford dentist, Dr. Wells, extracted teeth painlessly from patients rendered unconscious by the inhalation of nitrous oxide. Prematurely, he undertook to demonstrate this wonder to a group of students at Harvard Medical School. Unfortunately the patient, a young man, struggled and cried out during the extraction, and though later he reiterated that he had been unconscious of pain, the skeptical audience would not believe the statement and jeered Dr. Wells as an impostor. This experience was too shocking for Dr. Wells and practically finished his career.

Dr. William T. G. Morton, a dentist of Boston, Massachusetts, had been an associate of Dr. Wells and probably was familiar with his limited use of nitrous oxide. In his efforts to find a means of relieving pain for his dental treatments, Dr. Morton, at the suggestion of a well-known Boston chemist, Dr. Charles Jackson, tried local application of sulphuric ether. He was prompted to experiment further with this drug on the family goldfish and pet dog. While so

[7] Keys, *op. cit.*, p. 24.

doing, he accidently put himself to sleep one day by inhaling the ether fumes, happily confirming his observations of the relative safety of the drug as a hypnotic.

After devoting much time and effort to those studies, he succeeded in persuading an outstanding surgeon of the Massachusetts General Hospital, Dr. John C. Warren, to allow him to prove his discovery of the efficiency of ether vapor in preventing pain during a surgical operation. The patient chosen was a young man and he slept quietly under the influence of ether while a small tumor was excised from his neck by Dr. Warren, to the amazement of all the observers.

And so, convincingly, took place the historic event of the first public demonstration of surgical anesthesia. The endorsement of the highly reputable medical staff of the Massachusetts General Hospital assured the rapid spread throughout America and Europe of the knowledge and practice of this discovery.

The terms "anaesthesia" and "anaesthetic," two words of Greek origin defining the condition produced and the drug employed to produce it respectively, were suggested to Dr. Morton by the noted author and physician, Dr. Oliver Wendell Holmes. With the suggestion came a warning of the need for learned pondering in choosing a name "which will be repeated by the tongue of every civilized race of mankind." [8]

Ether anesthesia for control of the pain of childbirth was first used by Sir James Y. Simpson of Edinburgh, Scotland, in January 1847.[9] This practice met

[8] Fulton and Stanton, *op. cit.*, p. 51. Albert H. Miller, The origin of the word "Anaesthesia." New Eng. J. Med., 197:1218.

[9] Fulton and Stanton, *op. cit.*, p. 72.

with severe criticism from adherents of the stern religious belief of the period, especially members of the Calvinist clergy who taught that it was sinful to so thwart the curse pronounced on womanhood by the disobedience of Eve in the Garden of Eden. But Dr. Simpson, a canny Scotsman with a warm heart, in rebuttal also cited the Bible, Genesis 2:21, claiming that God set a precedent for anesthesia when, on creating Eve, He "made a deep sleep to fall upon Adam" for the removal of his rib.[10]

However, the controversy continued until 1853 when Queen Victoria gratefully accepted anesthesia for the birth of her eighth child, Prince Leopold, thus giving court sanction to a blessing the general public was anxious to enjoy.[11]

Hoping to find a more pleasing drug than ether for his purpose, Dr. Simpson experimented on himself and a few interested medical friends, finally demonstrating the anesthetic properties of chloroform in November 1847. Being more agreeable to inhale and of greater potency, for a while chloroform seriously challenged the supremacy of ether, but time proved it inferior from the standpoint of safety.

With the acceptance of surgical anesthesia as an established fact, interest in nitrous oxide revived, and the gas became the standard anesthetic for brief dental extractions. Anesthesia for general surgery was necessarily limited to ether and chloroform until the First World War, 1914–1918, when the need for a safer anesthetic drug for patients who had to be operated upon while still in a state of shock stimulated interest in nitrous oxide. It was found that, when nitrous oxide was combined with pure oxygen instead

[10] Keys, *op. cit.*, p. 34.

[11] Herbert Thoms. *Anesthésie à la Reine.* Am. J. Obst. & Gynec., 40:840.

of air to prevent asphyxial symptoms, results for this type of patient were surprisingly good. Thus impetus was provided for the designing and manufacture of suitable apparatus for administering "gas-oxygen."

Scientific research has remarkably enriched the world in many different fields of endeavor during the last few decades, and innovations in anesthesia were to be expected. The first to be realized was the introduction of ethylene gas, a volatile hydrocarbon, in 1923, clinical proof of its suitability as an anesthetic agent having been first established at the Presbyterian Hospital in Chicago.

An interesting side light on the discovery of ethylene as an anesthetic is the fact that the research was started at the request of florists who suffered heavy commercial loss in growing carnations, the well-developed flower buds failing to open. Chemists were able to prove that the 4 per cent ethylene commonly present in illuminating gas used for lighting the greenhouses was responsible for this "sleep of the flowers."[12] Considered first as a harmful poison, further research emphasized the beneficial effects of the gas as an anesthetic.

Another gaseous hydrocarbon, cyclopropane, of much greater anesthetic potency was added to the list in 1933. It had been sponsored clinically by Dr. Ralph M. Waters of Wisconsin.[13]

At about the same time, a volatile liquid anesthetic, Vinethene (divinyl ether), was synthetized by a group of California pharmacologists. After extensive clinical studies at the medical school of the University of Pennsylvania, and at the Royal Victoria Hospital,

[12] James Tayloe Gwathmey, *Anesthesia*, p. 712.

[13] Ralph M. Waters and Erwin R. Schmidt. Cyclopropane anesthesia. J.A.M.A., 103:975.

Montreal,[14] this new drug, too, became generally available.

Investigation, particularly by German chemists, of the anesthetic properties of nonvolatile drugs resulted in the addition of Avertin (tribromethyl alcohol) to the list. It is given by rectal instillation and was first used clinically in America in 1927. Following this, in 1933–1934, two anesthetic drugs for intravenous use became available, Evipal soluble (hexobarbital soluble) and pentothal sodium, which are short-acting derivatives of barbituric acid. Credit for the clinical introduction of pentothal sodium is due Dr. John S. Lundy and collaborators of the Mayo Clinic.

Cocaine, an alkaloid of the leaves of the tropical coca tree, had been discovered and named by the German chemist, Albert Niemann, in 1860. Proof of its efficacy as a local anesthetic, when applied topically to mucous membrane, was established by Carl Koller, a Viennese surgeon, in 1884. It was then adopted by European surgeons in the specialties of ophthalmology and otolaryngology. Dr. William Halsted of Johns Hopkins Hospital, Baltimore, Maryland, extended the use of cocaine to the field of general surgery by the hypodermic injection in and about nerves now called "nerve block." The high toxicity of cocaine caused search for safer synthetic drugs of a similar nature. Several have been found over the years, notably Novocain (procaine hydrochloride), also of German origin, which since its birth in 1904 has well stood the test of time and still holds supremacy as a local anesthetic.

As the advent of controllable anesthesia gave impetus to the widening of the scope of surgery, so the ambitious daring of the modern surgeon in tackling

[14] Wesley Bourne and Douglas W. Sparling. Some aspects of vinyl ether (vinethene) anesthesia. Anesth. & Analg., 14:4.

disease and malformation, even in the most remote and vital regions of the body, spurs on the alert anesthetist in striving for perfection in the "art of anesthesia." This infers not only thoroughness in knowledge and good judgment but also skill and ingenuity in overcoming the manifold and mechanical difficulties that may be encountered, always, of course, with the safety of the patient uppermost in mind.

Despite the advantages gained by the addition of new drugs and refinements in technique, the perfect anesthetic has not yet been found; all those of the present have their drawbacks, and so the search goes on. Doubtless, further valuable discoveries will be made, but, realizing the great variation in individual tolerance for drugs or even for simple foods in varying conditions of health and disease, one fears the prospect of this "perfect anesthetic" emerging may prove to be only a chimera. However, for the average case, the skilled anesthetist proves it is possible nearly to attain this goal of perfection by combining two or more agents in careful proportion, thereby enhancing the value and minimizing the danger inherent in the individual drugs.

Truly we have much for which to be thankful in the evolution of modern surgical anesthesia!

Chapter 2

PHYSIOLOGY OF ANESTHESIA

MANY drugs are known to have anesthetic properties, but few have been found to measure up to the requirements for surgical anesthesia in regard to safety and controllability.

It is essential that, in therapeutic dosage, the drug be innocuous to body tissues as a whole, causing no serious interference with normal organic functions, that it be effective in controlling muscle reaction to pain stimuli, and that the induction and recovery stages be reasonably brief and cause little discomfort for the patient.

Several plausible theories have been formulated as to how drugs produce the state of general anesthesia, but so far scientific proof has not been established. It is definitely known that nervous tissue is more sensitive to anesthetic drugs than are the body cells in general, that when a definite quantity of the drug is introduced directly into the blood stream, either by intravenous injection or by absorption through the alveoli of the lungs, a state of unconsciousness supervenes, the central nervous system being affected in the reverse order of its embryonic development. The higher centers become paralyzed before the vital centers of respiration and circulation are depressed; this, of course, is essential for the well-being of the patient.

One explanation for the hypersensitivity of nervous tissue to the volatile anesthetic drugs is that such drugs are, in general, lipoid solvents,[1] *i.e.*, readily soluble in fats, of which nervous tissue has a high proportion. The drugs are distributed to the body tissues through the blood stream, and the central nervous system has a very large blood supply. For prolonged satisfactory anesthesia, it is requisite that a uniform tension, or degree of saturation, of the drug be established throughout the whole system, but very short painful procedures can be effectively completed without discomfort to the patient when consciousness is first blotted out. Oftentimes this is of great benefit because of the brevity of the recovery stage.

Volatile drugs and gases, when inhaled, obey the well-recognized law of gases in establishing and maintaining equilibrium of partial pressure throughout the living body, by passage from the area of higher concentration to that of lesser concentration until the partial pressure in both areas is equalized. (Partial pressure means that in a mixture of gases at a given pressure, the pressure of each is divided between the different gases in proportion to their relative volumes.)

The exchange of oxygen and carbon dioxide in maintenance of the metabolic process largely represents the function of the respiration. The anesthetic vapor permeates into the blood stream through the thin walls of the lung alveoli, *i.e.*, air cells, in conjunction with these gases. There it dissolves or forms a loose chemical combination with both the blood corpuscles and the plasma and, in turn, is passed on

[1] Yandell Henderson and Howard W. Haggard, *Noxious Gases and the Principles of Respiration Influencing Their Action*, p. 83-84.

through the capillary walls into the body tissues as a whole.[2] Fatty tissue absorbs the drug most readily. All is constantly in a state of flux, or exchange, portions of all the gases passing on into the venous system and back to the lungs. But as inhalation of the vapor continues, an increasing tension, or partial saturation, of the anesthetic drug is established throughout the whole system. When the degree of anesthetic tension sufficient for the control of pain reflexes is reached, the concentration of the vapor being inhaled must be reduced, or the anesthesia will progress to the point of serious depression, or paralysis, of the vital centers of the medulla. The degree of saturation required for adequate surgical anesthesia varies greatly according to the drug, or combination of drugs, used and the degree of pain stimuli to be controlled.

During the induction stage of anesthesia, the concentration of the drug in the arterial blood is higher than that in the venous blood; during the ideal surgical or maintenance stage, the drug concentration is about equal in both the arterial and venous blood; and when the administration of anesthetic vapor is stopped, the venous blood takes on the higher concentration and unloads the anesthetic into the lungs, through which most of the drug is eliminated.[3]

With the exception of chloroform, all of the drugs commonly used as surgical anesthetics are relatively harmless to normal body tissues when given with skill and good judgment. But it must be remembered that anesthesia is an abnormal condition and all anesthetics are potentially poisonous to protoplasm. When given in maximum dosage or in too high a concentration they may have fatal results. Debility and dis-

[2] C. Langton Hewer, *Recent Advances in Anesthesia and Analgesia*, p. 1.

[3] Henderson and Haggard, *loc. cit.*

ease lower resistance to these potentially harmful effects, and idiosyncratic reaction to the drug may occasionally prove an important factor in regard to safety. In other words, it should be understood that every anesthesia carries with it a potential risk to life, and under no circumstances should it be undertaken lightly.

Late in the eighteenth century, the great French scientist Lavoisier demonstrated the similarity of fire, or combustion, and breathing and proved that it is oxygen combining with carbonaceous matter that liberates heat and energy and, in the process, forms carbon dioxide.[4] The lungs serve as the portal by which oxygen enters the system and from which carbon dioxide is excreted, and since these gases are transported to and from the tissues and the lungs in the blood stream, the circulation of the blood must be considered an essential part of the respiration. A fire cannot burn without oxygen, and a prolonged deficiency of oxygen in the body will finally cause death.

The air we normally breathe contains approximately 20 per cent oxygen. That this quantity constitutes the low limit of oxygen essential to the well-being of our bodies is demonstrated by the increasing discomfort, rapid pulse, labored breathing, undue fatigue, and nausea that are experienced by mountain climbers as they approach high altitudes. This is explained by the fact that the atmospheric pressure is reduced as the altitude is increased, and consequently the quantity of oxygen in the air breathed is less. A similar deficiency will be produced in a patient breathing an anesthetic atmosphere that is deficient in oxygen, the severity of the symptoms being dependent upon the degree of oxygen deficiency and the general condition of the patient.

[4] Yandell Henderson, *Adventures in Respiration*, p. 5.

It is evident that some degree of oxygen deficiency will persist during the inhalation anesthesia when atmospheric air only is used as the means of providing oxygen, for the bulk of the anesthetic vapor automatically reduces the percentage of oxygen in the air breathed. In addition to this dilution of oxygen, narcotics, in varying degree, depress the respiration and circulation and thereby lessen still further the quantity of available oxygen in the body. They also interfere with the chemical processes involved in tissue oxidation.[5]

Normal respiration is dependent on the maintenance of the acid-base balance in the blood and tissues. This balance is effected by the interrelationship of an intricate system of physicochemical reactions of oxygen and the by-products of metabolism and by the adequate functioning of the lungs and kidneys as excretory organs.

The determining factors for the regulation of respiration are: the carbon dioxide of the alveolar air and of the arterial blood, which normally is kept very constant at a tension of 40 mm. Hg.; and the threshold, *i.e.*, sensitivity, for carbon dioxide of the respiratory center in the medulla. Increase of the tension of carbon dioxide or decrease of the respiratory threshold for carbon dioxide results in stimulation of breathing, and vice versa. Pain, fear, and emotional excitement of any kind decrease the respiratory threshold for carbon dioxide. The consequent stimulation of breathing lowers the carbon dioxide tension in the body system faster than it is being replaced, and this condition of "overventilation" is likely to induce apnea of varying degrees of severity, which in extreme instances may prove fatal.

[5] Samson Wright, *Applied Physiology*, p. 417.

With clearer understanding of the causes and appreciation of the dangers of the various conditions that may complicate anesthesia have come efforts and means for their prevention or control. It is now generally accepted that additional oxygen increases the safety of all anesthetics. Modern apparatus for the administration of inhalation anesthesia makes it readily possible for the anesthetist to adjust the proportion of oxygen and carbon dioxide, as well as that of the anesthetic drug, to suit the immediate need of each patient.

Chapter 3

METHODS OF INDUCING SURGICAL ANESTHESIA

THE methods commonly used for the control of pain during surgical operations can be grouped into three general classifications: general anesthesia, local anesthesia, and regional anesthesia. Each method may be relied upon individually, or they may be used in combination for the more difficult and resistant types of patients in order to reduce the possible danger of cumulative toxic dosage when used singly, or when the peculiar advantages of different methods are especially desired.

General anesthesia. This is, in particular, distinguished by loss of consciousness, which is initiated by introduction into the blood stream of an anesthetic drug readily soluble in blood and body tissues. Entry into the blood stream may be effected in three ways: (1) *Inhalation anesthesia* is the inhaling of a volatile liquid or gaseous anesthetic that, on reaching the alveoli of the lungs, will readily permeate into the arterial system. This is the original and most commonly used method, being entirely controllable. The volatile anesthetics are changed very little in the body and are excreted almost entirely by the lungs. Therefore, to lessen the percentage of the drug in the system, it is necessary merely to stop administering the drug and to keep the patient breathing. With maintenance of adequate respiration, the plane of anesthesia can be delicately adjusted by increasing or decreasing the quantity of the drug inhaled. (2) In *rectal anesthesia* certain solutions are absorbed readily through the mucosa of the lower bowel, and anesthesia can therefore be induced by rectal injection of the drug. The drugs most commonly used in this way are ether-oil mixtures in varying proportion, Avertin (tribromethanol) and paraldehyde. As the solution is injected en masse, even though it may be absorbed gradually and evenly (as has been claimed for ether-oil mixtures by Gwathmey,[1] the originator of the method), rectal anesthesia definitely lacks flexibility of control. (3) For *intravenous anesthesia* the most popular drug used at the present time is sodium pentothal, a dilute solution of which is injected slowly into any convenient vein. By securing the needle in the vein throughout the surgical procedure, the solution can be given intermittently and the plane of anesthesia kept well under control.

As with the three general classifications for surgical anesthesia, *i.e.*, general, local, and regional, these three types of general anesthesia may be used singly or in combination.

Local anesthesia. The term implies the desensitizing of a limited, superficial area of the body without interference with consciousness. The two usual methods for producing this effect are: (1) The *topical* application to mucous membranes of the alkaloidal drug cocaine, or a derivative thereof. (2) *Hypodermic* injection of a dilute solution of the nonirritating sodium

[1] Gwathmey, *op. cit.*, p. 439.

salt of a synthetic drug; Novocain (procaine hydrochloride), derived from benzoic acid, is the most commonly used. These drugs have a depressing effect on the superficial nerves and interfere with conduction of pain impulses. The sensory nerves are affected first.

Regional anesthesia. This denotes control of pain, without interference with consciousness, in a wider, deeper area of the body than in local anesthesia. This may be accomplished in four ways: (1) *Nerve block* is produced by the injection of a local anesthetic solution in the region of a nerve trunk, or other large nerve branches, blocking impulses throughout its, or their, ramifications. (2) *Spinal anesthesia* is the injection of the solution into the subarachnoid space, preferably through the third or fourth lumbar interspace, thus avoiding injury to the spinal cord, which normally does not descend beyond the second lumbar space. Mixed slowly with the spinal fluid, the drug bathes the roots of the spinal nerves and desensitizes approximately the whole lower half of the body. Care must be taken to avoid paralysis of the muscles that affect normal respiration. (3) *Caudal* or *epidural anesthesia* is the injection of the solution through the sacral hiatus, the drug entering the spinal canal below the dural sac and reaching the nerves emerging from it. This procedure induces anesthesia in the low pelvic, perineal, and anal regions, with the complete avoidance of the risk of too high an area of anesthesia by diffusion of the drug in the spinal fluid. (4) *Refrigeration anesthesia*—a limb can be amputated painlessly after it has been adequately packed in chopped ice, or snow, for a specified time, a tourniquet being applied during the refrigerating process. This causes a marked slowing down, or cessation, of metabolism in all of the cells of the chilled area—a condition that has been compared to the state of hibernation natural to some wild animals. Its special field of usefulness is in the amputation of a limb for advanced diabetic or arteriosclerotic gangrene, for gas-bacillus gangrene, and for severe traumatic injuries complicated by acute infection. Advantages claimed for refrigeration anesthesia in these types of cases are: (a) slowing down of bacterial growth with consequent lessened spread of toxin from the infected area; (b) elimination of the additional toxic element of an anesthetic drug; and (c) lessening of operative shock by virtue of the complete blocking of afferent nerve impulses by the gradual and thorough chilling of the whole nerve network of the area involved.[2]

Many conditions may influence the selection of the anesthetic drug and of the method for its administration. Except in the most well-equipped and up-to-date clinics, the ability and experience of the anesthetist and the equipment available may necessarily be the deciding factors. Otherwise, the age and general condition of the patient, the site and type of operation and its probable duration, the possibility of the use of the actual cautery, diathermy, etc., are to be given studied consideration.

There is much difference, seemingly, in individual tolerance for anesthetic drugs, and a history of idiosyncrasy should be sought for and must not be ignored. Under some conditions it may be desirable that the patient retain consciousness, while the temperament of the patient may make this inadvisable. Other complicating problems are bound to arise; fortunately it is often possible to so combine drugs and methods that these can be solved satisfactorily for both the patient and the surgeon.

[2] Sergei S. Yudin. Refrigeration anesthesia for amputations. Anesth. & Analg., 24:252.

Chapter 4

PREMEDICATION

THE purpose of medication preliminary to anesthesia is usually threefold: (1) to allay fear, apprehension, and excitement and so reduce the body metabolism; (2) to diminish pain and thereby reduce the muscular reflexes caused by pain; and (3) to inhibit secretion of mucous glands and so counteract the stimulative effects of certain anesthetics on these glands. A fourth advantage may be added, namely, to induce amnesia so that the unpleasant experience will not be remembered.

Variation in tolerance, or reaction, to anesthetic drugs has been evident and commonly recognized since the inception of surgical anesthesia. The patients most difficult to anesthetize are not necessarily the large robust individuals. More often they are found among the thin, wiry, nervous, emotionally unstable types of people and the patients suffering from fever or acute toxicosis, such as the thyrotoxic cases. They are, in short, the types of patients for whom sedative medication frequently is indicated. So it is not remarkable that such medication has been used sporadically, prior to inhalation anesthesia, for many decades.

The volatile liquids, ether and chloroform, proved sufficiently potent to anesthetize all types of patients eventually, so sedative premedication was by no means a routine procedure until the advent, as surgical anesthetics, of the far less potent gases, nitrous oxide and ethylene. It soon was found that these "weak anesthetics," which normally must be used in concentrations of 80 per cent, are frequently incapable of inducing satisfactory anesthesia unless the oxygen combined in their clinical use is reduced gravely below the 20 per cent atmospheric oxygen to which the human body is so delicately geared to function.

In 1924, Dr. A. E. Guedel first pointed out the significance of the metabolic rate, and consequent degree of reflex irritability, in relation to anesthesia.[1] He emphasized the fact that increase of metabolism from any cause necessitates increase of oxygen consumption. At the same time a higher concentration of the anesthetic drug in the body tissues is required for control of the increased reflex irritability. This combination is impossible of achievement with a single anesthetic drug of low potency, so it is now generally recognized that preoperative sedation is not only desirable from the standpoint of the patient's comfort but may be essential for the safe conduct of the anesthesia.

Emotional excitement, pain, fever, and certain toxemias increase metabolism, and adequate sedative premedication is helpful in preventing or controlling these complications. The drugs most commonly used for this purpose are the alkaloids of opium, especially morphine sulfate, Pantopon, and codeine, and the moderately short-acting barbiturates: Nembutal, Amytal, Seconal, etc. The alkaloids of belladonna—atropine

[1] Arthur E. Guedel. Metabolism and reflex irritability in anesthesia. J.A.M.A., 83:1736.

and scopolamine—are useful in diminishing secretion of mucus.

The use of a routine form of dosage for medication of any kind is deplorable, for there is much difference in individual tolerance for drugs under conditions of both normal and impaired health. For instance, the basal metabolic rate varies considerably in different age groups as well as under abnormal conditions of health, and the rate of destruction of the opiates in the body depends largely upon the rate of the metabolism of the individual concerned. Again, if the patient is in pain, scopolamine and the barbiturates, given without morphine, may cause delirium and restlessness instead of somnolence. Consequently, selection and dosage of all medication should be carefully adjusted to the need of the individual patient. This need will vary in accordance with the age and the state of physical and mental health of the patient and with the anesthetic drug, method of anesthesia, and type of surgical operation to which he is to be subjected.

The possibility of idiosyncrasy to these drugs has to be given consideration. A good method for proving the validity of a history of idiosyncrasy is to first give small test doses of the drug so that the effect may be noted and the originally calculated dose omitted should this seem advisable. Some similar drug for which the patient shows better toleration may be substituted or a change made in the choice of the anesthetic.

It should also be clearly understood that the therapeutic dose of a drug that might safely be given by hypodermic injection into the tissues may be critically toxic if it is injected directly into the blood stream. Consequently, hypodermic injection should always be preceded by slight aspiration through the needle, after it is inserted, to make certain that a blood vessel has not been accidentally punctured. The needle should then be slightly withdrawn and the solution injected slowly. If blood is aspirated, the needle should be entirely withdrawn and reinserted a little distance from the original puncture.

A hypodermic injection will be more quickly absorbed and cause less local irritation if it is given sufficiently deep into the tissue so as not to cause an inflamed wheal at the site of injection.

The order in which premedication is commonly given is: (1) a sedative such as Nembutal (pentobarbital) at bedtime, to insure the patient a restful night; (2) morphine, given subcutaneously, preferably three-quarters to one hour before operation, to allay apprehension and diminish pain, and thus to reduce metabolism somewhat and increase the effectiveness of the anesthetic; (3) atropine or scopolamine, given subcutaneously with the opiate, to inhibit secretion of mucus in the air passages and so offset the stimulating effect of some anesthetics, especially ether and Vinethene, on the mucus glands. Atropine is rather the more effective for this purpose and, to a limited extent, offsets the respiratory-depressant effect of morphine. Normally scopolamine contributes a definite sedative effect and desirable amnesia.

Preliminary medication should be given sufficiently early for the full effects of the drug to be apparent by the time the anesthetic is started. This is especially important in the case of ether because of the danger of so high a concentration of ether being established in the system during the induction stage that, by the time the opiate attains its maximum effect, a condition of serious apnea may develop. The primary toxic effect of both of these drugs is depression of respiration. This risk is present also in regard to the barbiturates, though to a lesser extent. In short, preoperative sedation supplements anesthesia and reduces the quantity of the anesthetic that it is necessary or desirable to use in order to maintain a satisfactory plane of anesthesia.

The subcutaneous injection of morphine does not normally attain its maximum effect in the system until approximately one hour has elapsed. Should the patient be in a state of severe shock, or badly chilled from exposure to cold, absorption of the drug may be greatly delayed on account of the inefficient circulation of the blood under these conditions. Special warning to this effect was found to be necessary in the treatment of casualties during the war in order to prevent overdosage from too frequent repetition of the injection.

Morphine may be given intravenously when it is necessary, or desirable, to hasten absorption of the drug, but its effect will be of shorter duration. For use in this way, the tablet should be dissolved in at least 2 cc. of sterile water, or saline, and the solution injected very slowly (three to five minutes being allowed for the whole amount); the patient should be watched carefully meanwhile for untoward reaction so that, if indicated, the injection can be stopped. Maximum narcotic effect will be obtained within twenty minutes by the intravenous method of injection.

ADVANTAGES OF SEDATION

1. Morphine, a powerful narcotic, usually is helpful in promoting a state of drowsiness with a lessening of fear and anxiety in the patient who is facing a surgical ordeal.

2. The narcotized patient seems less sensitive to the

passage of time, so unavoidable delays will be less irksome to him.

3. The metabolic rate is somewhat reduced and the sense of pain appreciably dulled; in consequence, a lesser quantity of the anesthetic drug will be required in order to maintain satisfactory anesthesia.

4. With relatively short operations, the discomfort of the immediate postoperative recovery period is minimized.

5. The addition of one of the barbiturates enhances most of the good effects of the narcotic and gives the advantage of some degree of amnesia.

DISADVANTAGES OF SEDATION

1. Morphine depresses the rate and depth of respiration, and this may prolong the induction of inhalation anesthesia.

2. This drug retards gastric and intestinal secretion and motility, thereby causing flatulence and constipation.

3. Its primary effect of stimulation of the medulla may cause nausea and vomiting, and this distressing operative sequence not infrequently can be traced to the morphine that has been given rather than to the anesthetic drug. (Goodman and Gilman suggest that this discomfort may be prevented in some cases if a small portion of the drug is injected and the remainder given fifteen to twenty minutes later; the hypothesis being that the small initial dose will cause a minimum of primary medullary stimulation, with the final dose exerting the secondary, or depressant, effect only.) [2] Some patients who are nauseated by morphine seem to have more tolerance for Pantopon

[2] Louis Goodman and Alfred Gilman, *The Pharmacological Basis of Therapeutics*, p. 204.

(Omnopon), a mixture of purified alkaloids of opium including approximately 50 per cent by weight of morphine.

4. Occasionally, idiosyncrasy to morphine may be manifested by restlessness and excitement, continued cerebral stimulation rather than the usual subsequent depression.

5. By contracting the pupil of the eye, morphine disguises one of the valuable signs of the plane of anesthesia in the maintenance stage.

The effects of codeine are in every way milder than those of morphine, and this drug is unique among the derivatives of opium in that, when the maximum therapeutic dose of 60 mgm. is exceeded, the toxic symptoms are those of stimulation and excitement rather than depression.[3]

Opium derivatives, as a whole, depress the respiratory center and cause increase of intracranial pressure, so usually they are contraindicated prior to surgery for intracranial lesions. These drugs are also to be avoided in obstetrics during the last few hours of labor, because of the danger of the narcotic seriously delaying the spontaneous respiration of the baby at birth.

A new synthetic drug, Demerol (merperidine hydrochloride), is now in process of clinical evaluation as a substitute for morphine. This drug, it is claimed, ranks between morphine and codeine in its narcotic action. In comparison with morphine, it does not depress the respiration, does not constrict the pupil, is not constipating, is less frequently followed by nausea, and drug addiction less often results from its prolonged use. Encouraging reports have recently come from obstetric clinics of the analgesic effectiveness of Demerol during labor without causing respiration

[3] *Ibid.*, p. 206.

difficulties in the baby.[4] Demerol inhibits secretion of saliva and mucus, causing dryness of the mouth and thirst, so the additional use of atropine is not indicated.

The other two drugs commonly used in preanesthetic medication are atropine sulfate and scopolamine hydrobromide (hyoscine). The specific action of these drugs, for this purpose, is to offset the stimulating effect which some anesthetics exert on the salivary and mucus glands of the air passages, by inhibiting secretion of these glands. Their depressing effect on the parasympathetic nervous system also helps to counteract respiratory difficulties, such as laryngospasm, occasionally met with during anesthesia and precipitated by stimulation of that system from various causes.

Atropine and scopolamine stimulate the respiratory center. So, to a limited extent, they decrease or counteract the depressant effect of morphine on that center. Being mydriatics, they also tend to combat constriction of the pupils caused by morphine.

Comparing atropine and scopolamine, it is to be noted that atropine is somewhat more effective as an antispasmodic and in the control of excessive secretion of mucus, while scopolamine, in addition to these attributes, contributes psychic sedation and amnesia. Idiosyncrasy is more commonly met in the use of scopolamine than with atropine.

The need for a means of controlling the secretion of mucus will be apparent when it is realized that the fumes of the volatile liquid anesthetics, especially when given in high concentration, are irritant to the mucosa of the air passages, frequently causing a copi-

[4] Gordon Gilbert and Alfred B. Dixon. Observation on demerol as an obstetric analgesic. Am. J. Obst. & Gynec., 45:320.

William R. Schumann. Demerol (S-140) and scopolamine in labor, a study of 1,000 cases. Am. J. Obst. & Gynec., 47:93.

ous flow of saliva and mucus. This abundance of mucus may increase the hazard of anesthesia in several ways: (1) the fluid, saturated with ether, constantly bathing the sensitive bronchial epithelium may cause serious irritation and bronchitis; (2) plugs of mucus may become lodged in the narrow passages of the bronchioli, giving rise to the possibility of subsequent atelectasis and pneumonia; (3) a coating of mucus on the walls of the lung alveoli may delay absorption of the anesthetic vapor into the blood stream; (4) mucus, churned to a froth by the breathing, may seriously obstruct the airway and interfere critically with the exchange of oxygen and carbon dioxide; and (5) some of the ether-saturated fluid will be swallowed and so aggravate postoperative nausea and vomiting.

Everything considered, it is evident that successful premedication depends upon good judgment in evaluating a drug, or combination of drugs, in accordance with the advantages and disadvantages that they afford and in relation to the state of disability of the individual patient.

Chapter 5

GENERAL IMMEDIATE PREOPERATIVE AND POSTOPERATIVE CARE OF PATIENT

THE natural first reaction of the patient to the prospect of having to submit to a surgical operation, however slight from the surgeon's point of view, is one of more or less resentment and apprehension if not profound fear. Admission to the hospital is itself disturbing and exciting, but with a little kindly understanding and tact on the part of the nurses and attendants, the patient, unhurried, usually soon adjusts to the change more easily than he anticipated. So, whenever possible, it is advisable that the patient be admitted to the hospital at least a day before operation, for adjustment and observation.

Though the need for surgical intervention may be readily evident, a careful preoperative general physical examination and laboratory studies of blood and urine are indicated to determine the patient's probable tolerance for anesthesia and operation, and time is required for adequate arrangement for preparatory or supportive treatment, should such become necessary. It is important also that the alimentary tract be given special preparation.

Care in detail. Except when especially contraindicated, as prior to surgery for acute gastric disease or intestinal obstruction, an easily digested diet, rich in carbohydrates (to increase liver glycogen), may be given with advantage up to the night before operation. Water should be allowed freely to within two to three hours of operation, since it is readily absorbed from an empty stomach. Rarely will a patient ask for a drink of water in the early morning, so it is a good rule to include a glass of water, hot or cold according to the patient's preference, in the routine preoperative morning treatment; this will do much to alleviate later thirst and to promote normal kidney function. When possible to avoid it, forbidden food should not be displayed in the feeding of other patients, especially when the patient awaiting surgery is a child.

Proper preoperative preparation of the bowel will help greatly in preventing postoperative "gas pains," and this usually includes a thorough cleansing enema. Preferably, this enema should be given in the early evening prior to operation. The order commonly written "enema till clear" carries the assumption that the enema will be inefficiently given—a reflection on the nurse! Such procedure is needlessly tiring to the patient, and some of the fluid may be retained and the bowel continue in a state of irritability. This is especially annoying if the enema is given within a few hours of the surgical operation. One injection, given slowly and carefully, should be effective in emptying the lower bowel.

Commonly, simple sedative medication is ordered to be given at bedtime to assure the patient a restful night before the surgical ordeal. A hot drink, such as milk or malted milk, given at the same time may aid in inducing sleep. It is most important that all necessary examinations and treatments have been completed before such sedation is given. Otherwise its effect is spoiled. If the cleansing bath also is given the evening before operation, there will be little need for disturbing the patient too early in the morning.

Thorough brushing of the teeth and rinsing the mouth with a mild saline or antiseptic mouth wash just before going to the operating room is refreshing and a safeguard against respiratory infection. All detachable dentures should be removed in the patient's room; the final responsibility for removal of such, of course, rests with the anesthetist, but these expensive small things may easily be lost in a busy operating room. Dental bridgework especially is a source of danger to the unconscious patient; fatalities have resulted from lacerating effects of the attached metal clips when such articles have become displaced and swallowed.

Hairpins and combs may cause injury to the scalp during unconsciousness and should be previously removed. Long hair should be combed and braided.

The lips and fingernail beds are valuable indices of proper oxygenation of the blood and should be devoid of artificial coloring; this fact should be tactfully explained to women patients who insist on applying such cosmetics prior to general anesthesia.

The patient should be requested to empty the bladder just before leaving for the operating room; and the quantity of urine, time of voiding, or inability to do so should be noted on the patient's chart. Time is valuable but the thoughtful, efficient nurse is careful to avoid giving the patient an impression of being hurried. By her sympathetic yet cheerful and confident attitude she can greatly mitigate the patient's natural reaction of apprehension and of repugnance

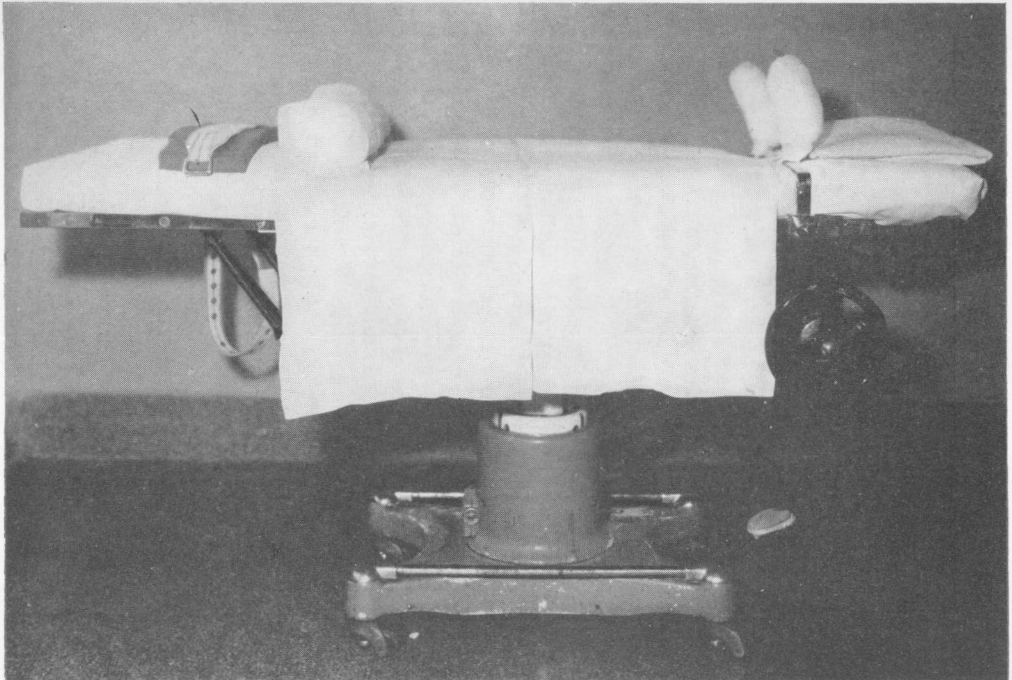

Figure 1. Well-padded operating table.

to the humiliating indignities that unfortunately are commonly a necessary adjunct to the preparation for major surgery.

The environment of the operating-room suite may well prove distressing to a nervous person, and the patient should not be kept waiting there just for the convenience of the operating-room staff. However, the feeling of being hurried is also unfortunate, and in a busy department these drawbacks may have to be counteracted by sedative premedication to dull the patient's sensitivity. Every nurse should understand the importance of not deceiving a child; such too-common practices as telling a child, "You are going to have your picture taken," when he is en route to the operating room are inexcusable, for the proven falsehood naturally undermines his trust in everyone connected with his hospital treatment. In contrast, very commendable is the kindly effort of the head nurse of a children's ward who, with rare psychical understanding in her love of children, teaches them an amusing jingle to be sung as a chorus. The jingle describes the helmets and gowns of green, etc., worn by the doctors there, and is accompanied by a delightfully graphic fling of bandage scissors to the floor by the leader of the group; all of which stimulates a child's interest in the coming experience, without the element of deceit. It is desirable that the patient be taken to the operating room by a nurse with whom he is familiar and who will introduce the nurse or anesthetist to whose care he is being entrusted.

Transfer to operating table, for general anesthesia. As a general rule, a mattress in two sections can be used to cover the operating table; this and a firm roll placed under the knees when the patient is to lie in the supine position will aid in relieving muscle strain and in preventing postoperative backache. (If the patient has inadequate circulation in the legs, however, it is best to omit the knee roll as a precaution against further circulatory interference from pressure in the popliteal space.) The mattress, preferably filled with hair, should be approximately three inches in thickness and covered with waterproof material over which is placed a folded sheet. A simple means for lifting the patient from table to bed or stretcher is provided by the placing of two straight abdominal binders on top of the mattress and sheet, under the patient's body. (Figure 1.) The ends of these binders can also be used to advantage in confining the patient's arms during anesthesia.

Wrist straps made of heavy flannelette (Figure 2) are harmless and effective as restraints when fastened securely to the sides of the table. The cuffs may be attached to the wrists when the patient is first transferred to the table, but with an adult the arms should never be evidently restrained while the patient remains conscious. Such ill-considered premature restraint suggests great discomfort to be experienced, provoking resistance by alerting the patient to a combative state of mind.

A strap, suitably cushioned to prevent nerve injury, can be inconspicuously passed under the table and over the patient's knees and fastened securely at one side of the table with the casual remark that it is done to safeguard the patient from falling off the narrow table. Straps and braces of all kinds need to be well cushioned, hands straightened in normal position, etc., in order to avoid the danger of serious circulatory interference or nerve injury.

For the patient lying in the prone position during anesthesia, it is necessary that the shoulders be firmly supported by pads placed on top of the mattress at

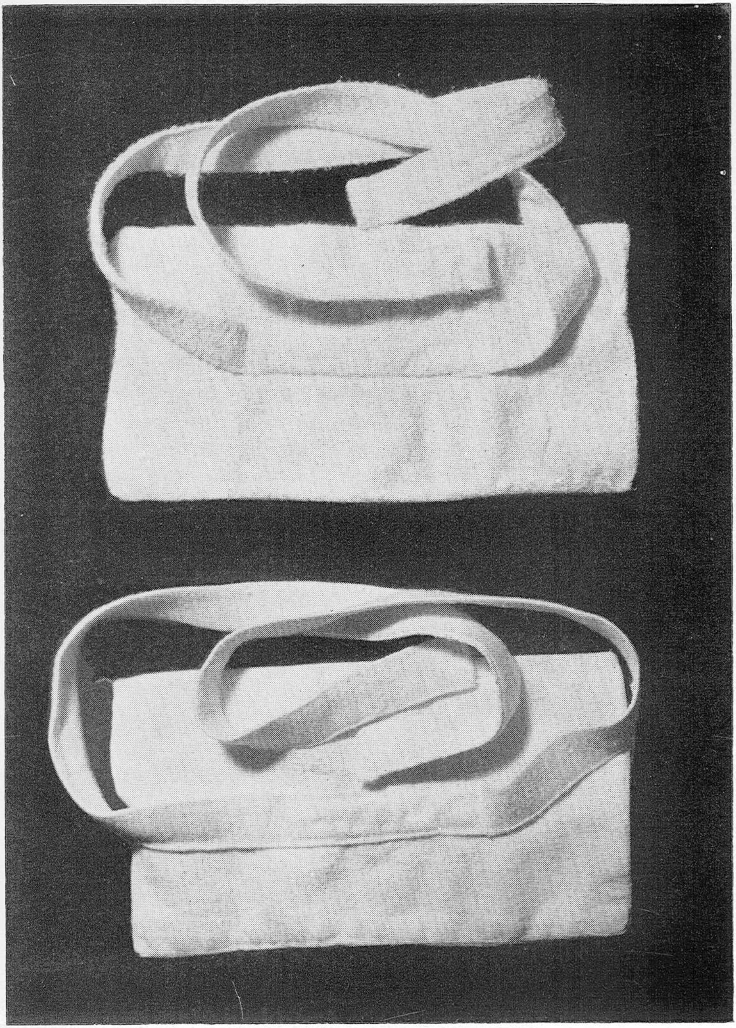

Figure 2. Wrist straps: soft, yet firm and washable.

each side. Separate pads are used in order to prevent inadequate chest expansion due to compression during profound muscular relaxation. The knee roll should then be placed under the front of the feet, to keep the toes suspended slightly from the mattress.

Small children may be wrapped up in a half sheet or small cotton blanket folded in half and laid on the table so that the open end lies under the child's neck; a single layer of the sheet is then passed at each side over an arm and under the body, the weight of which restrains movement of the arms; then the second layer of the sheet is passed over both arms and tucked under the body at each side. With a little ingenuity and imagination the whole procedure can be made into a game and then is seldom resented by the child. There is great satisfaction in being able to anesthetize most children in such a way that they fall asleep quietly and later have no fearful recollection of the ordeal and, usually, the smoother the induction of anesthesia the easier it will be to maintain a smooth surgical stage also.

Too heavy covering is to be avoided, especially in hot humid weather, because of the risk of heat exhaustion due to a combination of concentrated heat from high-powered surgical lamps and heavy coverings. These interfere with the evaporation of sweat and with the dissipation of body heat. The heat-regulating mechanism is upset in turn and high fever results. Such cases have been reported.[1]

To anyone unfamiliar with it, an operating room is likely to appear fearful and alarming, anything but a soothing place in which to "be put to sleep." So, whenever possible, a quiet side room should be chosen for the induction of anesthesia, with only an assistant

[1] Mortimer B. Genauer. Post-anesthetic heat stroke. Anesthesiology, 7:302.

present beside the anesthetist and patient. When this is not practicable for any reason and the anesthesia must be started in the operating room, the room should be kept as quiet as possible. The sorting and display of instruments must be delayed and general conversation stopped until the patient loses consciousness. The anesthetist should have everything prepared in readiness so that there will be no delay in the start of the induction when the patient is brought into the room. A properly conducted induction of anesthesia is rarely complicated by a troublesome stage of excitement. Absence of the excitement stage cannot be surely predicted beforehand, however, and an assistant who is capable of restraining an active patient, if necessary, should always be close at hand during the induction stage.

At the completion of the operative procedure, all wet coverings should be replaced by warm dry ones and the patient lifted gently into bed. Though the patient may still be unconscious, rough handling immediately following a major surgical operation may provoke a state of shock with serious fall of blood pressure.

Unless definitely contraindicated from a surgical standpoint, all surgical patients, when first transferred to bed, should be turned on one side with the upper knee flexed and a pillow tucked snugly at the back in order to maintain the lateral position. (Figure 3.) Care should be taken to place the head so that the neck is in normal contour in order to facilitate normal breathing and the expulsion of vomitus should such occur. A thin pillow may be helpful for this, and often adds to the patient's comfort. With the head properly placed in this way, the relaxed tongue of an unconscious patient will fall to the dependent side of the mouth thus providing a reasonably clear airway

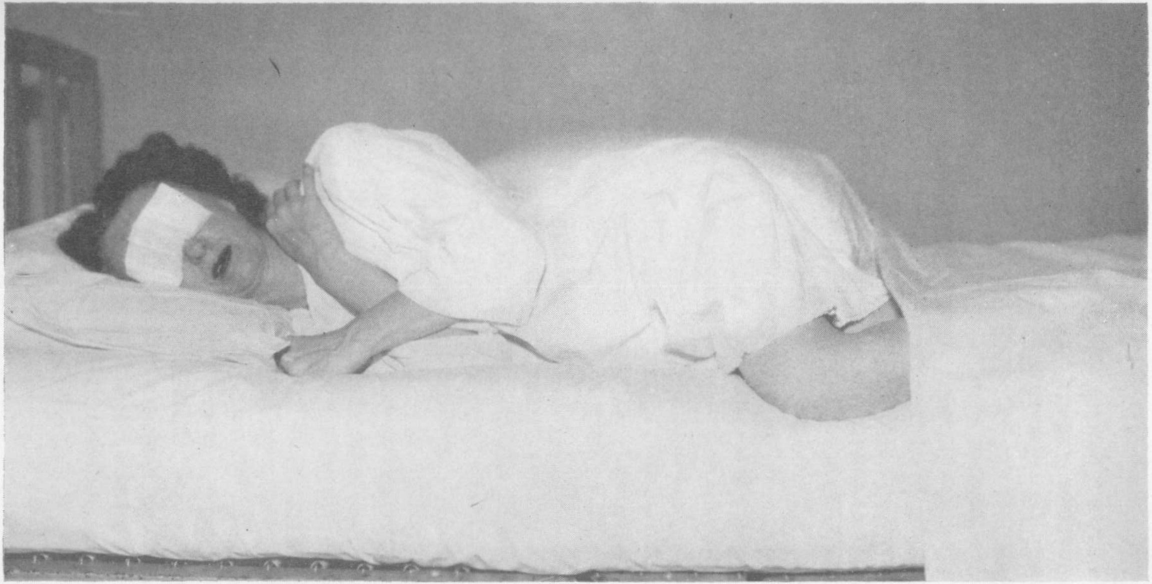

Figure 3. Desirable position in bed for an unconscious patient.

above it. Should the tongue relax against the posterior wall of the pharynx, the airway becomes almost completely blocked, a condition typified by a noisy snore or total suppression of breathing—the misnamed state of "swallowing the tongue." If such a condition occurs, it can be quickly corrected by grasping the lower jaw on both sides at the angle posteriorly and drawing the jaw forward so that the lower teeth come into line with, or slightly in front of, the upper teeth. The tongue is thus pulled away from the posterior wall of the pharynx. If it is not permissible to turn the patient on one side, an adequate airway may be maintained until the patient recovers consciousness by the insertion of a pharyngeal airway tube, either through the mouth or nostril. (Figure 4.) These details of safeguarding the patient from respiratory embarrassment are primarily the responsibility of the anesthetist, but emergencies may later arise and the nurse should be ready and able to cope with them.

For several reasons it is essential that the postsurgical patient be protected from drafts and insufficient covering in cold weather and from contact with people suffering from acute respiratory infections. Frequently there is loss of body heat during a prolonged surgical operation due partly to metabolic and circulatory disturbances and the sweating caused by some anesthetic drugs and partly to evaporation from severed tissues and serous surfaces. Also surgery and anesthesia, especially in major operations, lower resistance to acute respiratory infection from the germs that are always present in a quiescent state in the upper air passage. When the weather is hot, undue overheating of the patient by warm coverings, etc., is, of course, to be avoided, both for the comfort of the patient and for the danger of further loss of body fluids by excessive sweating.

To insure his safety, the anesthetized patient must be kept under continuous observation until the return to a conscious state is completed. This period can be used to advantage for the initiation of parenteral fluid therapy or other postoperative orders that might cause some discomfort during consciousness.

It may be well here to stress the fact that the common practice of surgeons in leaving "P.R.N." orders for sedative medication for the postoperative patient puts a heavy responsibility on the nursing staff. This is particularly true in the case of the powerful opiates and when the more depressant type of anesthetic has been given.

As a rule, a lesser quantity of a narcotic is required if it is given early rather than if it is delayed while the severity of the pain increases or the patient's ability to tolerate the pain decreases. But the time required for destruction of the drug in the body, or for its elimination, depends largely upon the rate of the body metabolism. Narcotic drugs lower the metabolic rate, and therefore the metabolism of a patient who is recovering from a prolonged surgical anesthesia is probably reduced. This is especially so when Avertin, pentothal, a deep plane of ether, or a combination of such drugs has been used. A narcotic drug for the relief of pain or restlessness may be indicated relatively soon after the completion of a painful surgical operation, even though the patient may not have completely recovered consciousness. But this additional medication will still further reduce the metabolism, and repetition of the dose calls for the exercise of experience and good judgment, with a realization of the significance of the metabolic factors. The average four-hour interval allowed for destruction of morphine in the system may be grossly inadequate under such circumstances, and the destruction of vital

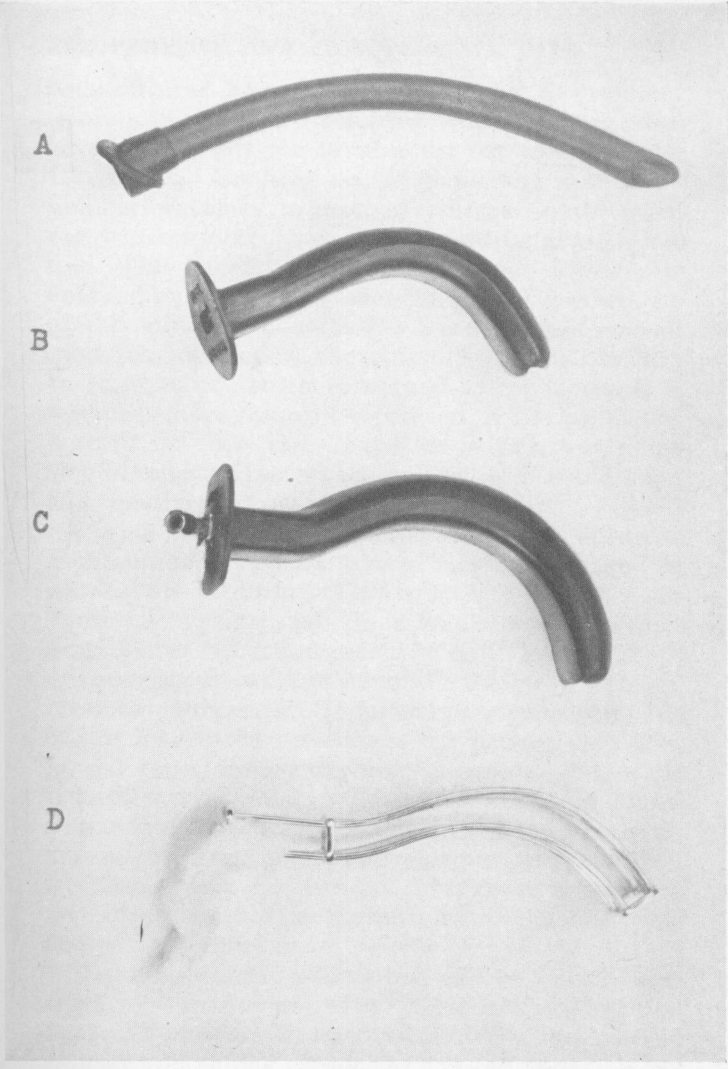

Figure 4. Pharyngeal airways. Available in various sizes and types and from various firms. The instruments illustrated are from the Foregger Co., New York. A) nasal tube, rubber; B) oral, rubber; C) oral airway and insufflation tube, rubber; D) oral, metal.

body cells can be caused by anoxia due to profound respiratory depression resulting when the nurse follows too literally the usual order for morphine "q. 4 h. P.R.N." Soothing details of nursing care oftentimes are sufficient to prolong satisfactorily the intervals between doses, and these should be given a fair trial. This danger of serious depression is less pronounced following the gaseous anesthetics for these are quickly eliminated, and unless a condition of surgical shock has developed, the patient's metabolism may be expected to return to normal as consciousness is regained. More frequent repetition of the prescribed narcotic for these cases may then be safe, and necessary in order to protect the patient from debilitating and unwarranted pain.

During the first few postoperative days, adequate expansion of the patient's lungs may be prevented by his shallow breathing. This may be a result of his "splinting" against the pain of an abdominal or chest wound or of restriction caused by tight dressing straps or bandages. In order to lessen the danger of development of postoperative pulmonary complications due to this inadequate ventilation, the patient should be moved several times a day from side to side (unless the type of injury prohibits this), and he should be instructed and encouraged to breathe deeply at intervals and to cough up mucus and phlegm which may collect in the deep air passages. This procedure should be followed despite the transient additional pain these efforts may cause him.

Desirable deep breathing can also be induced mechanically by the use of a "blow bottle"—a gallon bottle half filled with water and fitted with a pierced stopper and tubing through which the patient blows into the water vigorously enough to cause it to bubble actively.

Physiological stimulation of the respiration can be brought about by having the patient breathe a small quantity of carbon dioxide diluted with air or oxygen; 5 per cent carbon dioxide is usually sufficient. By the intelligent use of a gas-oxygen face mask and breathing bag, a single bagful of the carbon dioxide mixture can be rebreathed and will suffice for each treatment. The patient must be encouraged to inhale the mixture until stimulation of the respiration is evident (a few breaths will suffice for this), then the obturation valve is closed, to retain the gas in the bag, and the mask is removed from the patient's face. The stimulation of breathing gradually fades and, after a few moments of rest for the patient, the treatment is resumed. The usual order is for three such treatments at two to four-hour intervals, but the treatments are of no avail unless their purpose is understood and they are given intelligently and well. This treatment is also helpful for the relief of postoperative "gas pains."

Endotracheal catheter suction at intervals during the first few postoperative days may prove a lifesaving measure when other methods are ineffectual in clearing the deep-seated respiratory tract of accumulations of obstructing mucus.[2] When skillfully done it is not very disturbing to the patient.

[2] Cameron Haight. Intratracheal suction in the management of postoperative pulmonary complications. Ann. Surgery, 107:218.

Chapter 6

VOLATILE LIQUID ANESTHETIC DRUGS: ETHER, CHLOROFORM, ETHYL CHLORIDE, VINETHENE

ALL inhalation anesthetics are chemically almost unchanged in the body but are excreted through the lungs, loaded with the excess carbon dioxide of metabolism. If the exhaled vapor can be passed through a chamber of soda-lime (sodium and calcium hydroxide), which is, or can be, incorporated in all modern gas-oxygen machines, the carbon dioxide will be removed and the anesthetic restored to its original pure state.

Ethyl ether, the herald of surgical anesthesia a century ago, still holds prominence as the fundamental, relatively safe anesthetic drug, for it has a large margin of safety (the difference between the therapeutic and lethal dose); it is a volatile liquid of high potency; and it is easily portable and can be used effectively with very simple apparatus. Consequently, if limited to one drug only, most probably ether would be the first choice of surgeons and anesthetists in general. But from the patient's point of view, ether is the least agreeable, largely because prolonged postanesthetic nausea and vomiting are more common than with the other anesthetic drugs. Happily, under average circumstances, a wide choice of anesthetics is now available.

The severity of the symptoms of nausea and vomiting depends largely upon the degree of saturation of ether in the body system. The small quantity of ether sometimes desirable or necessary to stabilize the effect of a less efficient, though less toxic, drug may have little or no disagreeable sequence.

ETHER ANESTHESIA

Ethyl, or sulfuric, ether, $(C_2H_5)_2O$, is a clear colorless volatile liquid with a boiling point of 36.5° C. It is highly inflammable but, as the vapor is approximately two and a half times heavier than air, the area of danger can be fairly well limited and kept under control. Ether can be administered for anesthesia in several ways: (1) by pouring, or dropping, the liquid on a semiopen cone or face mask; (2) by intrapharyngeal insufflation of the vapor; (3) by a closed method of rebreathing, for which oxygen and a complete gas-oxygen machine are required; (4) by rectal injection of liquid ether combined with a bland oil; and (5) as a supplement to other less potent anesthetic drugs.

The simplicity of the first method of administration, the semiopen method, makes this the most commonly used method. It was the original way in which ether was used, though the method has been varied, modified, and improved over the years.

The second method, intrapharyngeal insufflation, is of special value as a simple means of maintaining a smooth plane of anesthesia for surgery in the vicinity of the face, mouth, and throat when, for obvious reasons, a face mask could not well be used. After the induction of surgical anesthesia has been brought about in some other way, insufflation of the vapor is made by means of a nasal catheter, or oral tube, which is inserted so that the tip of the tube will lie in the nasopharynx. A motorized machine can be used for vaporizing the liquid ether, or a simple apparatus comprising a bottle and hand bulb can readily be improvised for the purpose.

The third method, the closed method, offers certain advantages. The more important of these is the fact that an abundance of vital oxygen can be included in the atmosphere breathed by the patient. When ether is diluted with air only, some degree of oxygen deficiency will persist during anesthesia on account of the bulk of ether vapor and the latent depressant effect of the drug on the respiration. It is generally accepted that some addition of oxygen increases the safety of all anesthetics. Another advantage is the fact that the patient breathes a warm moist atmosphere instead of the icy coldness produced by ether evaporation within the face mask. Still another is that contamination of the operating-room air with ether vapor is greatly minimized. Finally, normal respiration can more readily be maintained. Abnormalities of respiration induced by the anesthetic, or emotional condition of the patient, can seriously upset the fine adjustment of the percentage of carbon dioxide in the blood stream. Maintenance of the normal percentage of carbon dioxide is essential for proper functioning of the vital organs of the body.

In order to induce anesthesia by the fourth method, rectal injection of ether oil, four to six ounces of a 50 per cent to 75 per cent ether-in-oil mixture are injected into the rectum. Within a few minutes ether can be detected on the patient's breath, for the drug is excreted almost entirely through the lungs in the same way as when ether is inhaled. Despite the oil, the solution is irritating to the mucosa, and it should be injected very slowly in the hope of establishing a local analgesia in the bowel to prevent expulsion of the enema. It is good practice to give the injection while the patient is in bed so that an emotional upset, due to the conscious patient being removed to the operating room, may be avoided.

The advantages of this method are: (a) the face can remain uncovered; (b) when given in correct dosage, this form of ether anesthesia is nonirritating to the lungs and air passages; (c) it does not seriously affect the blood pressure; and (d) effective obstetrical analgesia can be induced in this way simply and without injurious effects to mother or infant.

The disadvantages of this method are: (a) uncertainty in regard to individual patient's tolerance for the drug over a long period of time; (b) inflexibility of control of the depth of anesthesia, as in the case of any drug which is given in single dose; and (c) the likelihood of a mild delirium persisting throughout the period of anesthesia.

As the fifth method implies, a supplementary effect, small quantities of ether given at intervals will enhance the anesthetic effect of less potent drugs without detracting greatly from their own peculiar advantages.

Illustration of the induction of ether anesthesia will be given in detail for the "drop method" only.

A stimulating maxim for the anesthetist to remember is: "A difficult and bad anesthesia is the fault of the anesthetist, and not of the patient," or, it might be added, of the anesthetic drug employed. This saying is especially applicable to the ether-cone method by which, for decades, the induction of anesthesia too often resembled suffocation for lack of a little thoughtful understanding on the part of the anesthetist.

Concentrated ether vapor is irritating and difficult to breathe unless a tolerance for it is worked up gradually. This holds true even in the case of patients already unconscious by induction with some other means of anesthesia. Failure to appreciate this obvious fact for so long generated the common fear of "taking ether." As a rule, the vapor was first applied in a far too concentrated form that was really nonrespirable; this caused the patient to obey the law of self-preservation and "fight for breath." But the more he fought the more he was restrained and forced to endeavor to breathe the irritating vapor, and thus a "vicious circle" was set up. It is quite understandable that a repetition of such an ordeal would be dreaded.

When properly administered, "open-drop ether" is not at all difficult to breathe and of itself rarely causes troublesome coughing. The special disadvantage of confining the induction of anesthesia to ether is that the abnormal sensations involved in the gradual loss of consciousness persist for a relatively long time, and the patient should be reassured repeatedly during this time. A pleasing rule in the case of a child is to distract his attention from the discomfort by telling him a story suitable to his age and temperament. It is a gratifying compliment for the anesthetist later to be sent for by the little patient "to come and tell the end of the story because I fell asleep in the middle of it."

The vapor of ether is not injurious to the eye but the liquid drug, if accidentally dropped into the eye, is very irritating to the mucosa, and this irritation is the more pronounced the longer evaporation of the drug is delayed. Friction of any kind on the exposed eyeball may have serious consequences; corneal ulcers have resulted from prolonged contact of a rubber-cushioned nitrous oxide–oxygen face mask with the open eye. A wise rule for the anesthetist is to train oneself automatically to protect the patient's eyes at all times, both by keeping the eyelids closed and by preventing the possibility of liquid ether getting into the eyes either from careless handling of the ether can or from seepage from a saturated face mask. (The mask should never be allowed to become saturated with the anesthetic.) A drop or two of pure castor oil is soothing and harmless to the eye and, when applied early, is of much value in counteracting the irritant effects of liquid ether.

Covering the eyes during anesthesia is a common rule, but for it to be of value, precaution must be taken against the use of faulty material for the purpose. If the covering rule is to be followed, a soft wad of dampened absorbent cotton or a sound piece of rubber tissue placed over the closed eyelids provides relative safety.

Technique for drop-method ether. The face mask should be of ample size to cover the nose and mouth of the patient and of sufficient height so that the moistened covering does not come in contact with the skin of the face. A double thickness of closely woven stockinette makes the best vaporizing medium as a covering for the mask, though six to eight layers of gauze or a piece of bath toweling will answer this purpose very well. A dropper can be provided for the ether can in the form of a cork with a groove cut on two sides, in one of which a thin wick of rolled cotton is placed; or a large safety pin can be passed through the soft lead cap of the can and fastened to serve as a dropper.

An effort should be made to gain the patient's confidence and co-operation by explaining the procedure briefly. Describing the simplicity of the face mask and letting him breathe through it for a moment before any ether is applied will frequently allay any feeling of repugnance or claustrophobia he might have. Mention should be made that ether vapor is pungent but can be breathed easily in the way it will be given. The mask is then laid lightly on the face, neatly covering the nose and mouth, and the ether is started, allowed to fall slowly drop by drop for six to eight drops, then the rate of drop is increased gradually to as rapid a rate as possible without causing embarrassment of the patient's respiration. The rate of drop can be easily regulated by slight adjustment in the method of holding the can. The flow should be limited to drops, slow or fast as indicated, but never an uninterrupted stream.

Should any sign of embarrassment of respiration appear, or early efforts at struggling, the mask must be lifted momentarily and the rate of dropping the ether slowed somewhat, the patient being reassured meanwhile and encouraged to relax and breathe normally. Abnormally deep breathing is not helpful but tires and overventilates (reduces the carbon dioxide necessary to maintain normal respiration). This might precipitate a temporary apnea and so defeat the object of hastening the induction of anesthesia.

Even after consciousness is lost, it may be necessary to lift the mask occasionally to prevent the accumulation of too irritating a vapor, which, if allowed to continue, may cause congestion of the tongue and upper respiratory tract. A condition of stertorous breathing, tightly clamped jaws, and increasing cyanosis is typical of this state of congestion, which is due to an insufficiency of oxygen. The condition can be immediately remedied at this stage by the passage of a lubricated rubber tube or catheter through one nostril and behind the base of the tongue to the pharynx. This will allow the free entrance of air and is a much simpler and safer procedure than trying to force open a clenched jaw.

Once tolerance for a concentrated vapor of ether is established, it should usually be possible to complete the induction of anesthesia smoothly and quickly, with little evidence of excitement or discomfort on the part of the patient. However, it is to be remembered that an early effect of the anesthetic is the undermining of the patient's power of self-control, and the assistant must be alert to the possibility for need of restraint. This is commonly demonstrated by movement of the arms in an effort to remove the anesthetic mask, for which the patient may have felt some resentment as he fell asleep. Grasping the elbows and pinioning them to the operating table is the best way in which to control these movements, and with the arms under control the anesthetist should be able to keep the situation well in hand. This includes control of movements of the patient's head and deepening the plane of anesthesia. It should be borne in mind that resistance can frequently be quieted more effectively by lifting the mask from the face for a moment than by increasing the concentration of the anesthetic vapor.

Vomiting may occur during the induction period, especially if the stages are protracted. At the first sign of retching, the head should be turned to one side and an effort made to deepen the plane of anesthesia. Should vomiting occur, precautions must be taken for avoidance of the possibility of aspiration of the fluid by providing for its free expulsion from the throat and mouth. Lowering the head of the table, drainage by gravity, and the use of suctioning apparatus may be of value in this respect.

The beginner is often surprised by the relatively large quantity of ether that is required by the open-drop method to bring the patient to the surgical stage of anesthesia, but it should be evident that much of the ether dropped on the mask never reaches the patient's lungs but is blown off into the surrounding atmosphere as he exhales. The induction period can be inefficiently prolonged by a too generous flow of ether, in the evaporation of which the mask becomes too chilled and frosty for the vapor to penetrate the covering. The surgical "bad risk" kind of patient, because of his debility and poor resistance, as a rule is easily anesthetized but may also become critically depressed by the anesthetic drug, and special care must be taken to prevent this from happening. The most difficult patients to anesthetize are likely to be the high-strung nervous individuals and, of course, the drug addicts and alcoholics, who have established a high tolerance for intoxicants. The medical opinion that alcohol is not a stimulant applies also to the volatile anesthetics. The "stage of excitement," when it is evident, is ascribed to the drug's effect of releasing the patient's pent-up emotions by undermining his powers of self-control, *i.e.*, to the depressant effect of the drug on the higher mental centers.

Stages of anesthesia. These are classified as follows: (1) stage of analgesia, (2) stage of excitement or delirium, and (3) stage of maintenance or the surgical stage.

Stage 1, stage of analgesia: This stage is characterized by an increasing sense of unreality, by dizziness, ringing in the ears, lessening of the sensitivity to pain and touch, tingling and numbness in the extremities. But the sense of hearing is sharpened, and noise is intensified. (It is well to remember, in regard to anesthesia, that the sense of hearing is the last to be lost and the first to return and care should be taken to avoid remarks which it is undesirable that the patient should hear.) Control of the respiration in this stage is voluntary, and the patient should be encouraged to breathe normally; holding of the breath probably is an indication that the ether vapor is too concentrated, and the mask should be lifted momentarily. The flushing of the face and neck, increase of pulse and blood pressure, and active eyes with dilated pupils, which are commonly noted during the induction stages of anesthesia, are ascribed to the primary stimulating effect of the anesthetic on the sympathetic nervous system.[1] As the plane of anesthesia deepens, the alert, conscious expression of the eyes changes to a fixed stare, frequently with the eyeballs in an eccentric position.

Stage 2, stage of excitement: Loss of consciousness may be followed by delirium and muscular activity. But there is much variation in these reactions, and often they do not occur at all; much depends upon the skill with which the anesthetic is administered. During this second stage, the vital signs usually continue to show evidence of stimulation. The respiration may be irregular and become stertorous. The latter condition is due to some obstruction of the airway, probably congestion of the tissues caused by too great concentration of the ether. Approaching the completion of this stage, the respiration becomes rhythmic and peripheral muscular activity ceases. Loss of the eyelid reflex, *i.e.,* movement in response to touch, is the signal of the entrance to the third stage, during which the muscular relaxation and general appearance of the patient should resemble the condition of normal sleep.

Stage 3, stage of maintenance: The surgical stage is frequently referred to as embodying three planes. This

[1] Henry K. Beecher, *The Physiology of Anesthesia,* p. 8.

classification is based upon the degree of concentration of the drug which must be built up in the body tissues in order to prevent muscular reaction to painful stimuli. The degree of concentration varies in accordance with the severity of the pain. This in turn may vary according to the area of the body which is involved and the care with which sensitive tissues are being handled. The appearance of the eyes and the character of respiration are the guiding signs for recognition of these planes of anesthesia.

Generally speaking, the eye signs for the first plane are a slowly oscillating eyeball and a contracted pupil; those for the second plane, a quiet eye in normal position and a slightly widening pupil; and for the third plane, a still, dry eye with dilated pupil. Relaxation of the pupil in the third plane of anesthesia is of paralytic origin. (The corneal reflex, often referred to in relation to anesthesia, is lost at the beginning of the second plane.) Of course, these signs are not clear-cut; they may overlap, are progressive, and may be markedly altered by the effects of premedication.

The wise anesthetist learns to evaluate the character of the respiration and is guided largely by that most vital function. Throughout the surgical stage, the breathing should be regular with evident movement of the chest wall. The depth of respiration is of greater significance than is the rate, which may vary greatly in accordance with the age and state of health of the individual patient, and the type and quantity of premedication which has been given to him. Once this respiratory rate has been established for the case in hand, an increase in the rate is commonly the first sign of reaction to greater stimulation at the operative field, and this calls for deepening of the plane of anesthesia.

The more painful the surgical procedure, either due to the sensitivity of the tissues involved, or to the manner in which they are being handled, gently or roughly, the deeper will the plane of anesthesia have to be in order to prevent reaction to the pain. There is much difference in sensitivity of the body tissues. In a general way, areas of the skin, peritoneum, mucocutaneous borders, and joints are the most easily stimulated. The muscles, the brain, abdominal viscera, and bone are much less sensitive to surgical interference. The experienced anesthetist can adjust the plane of anesthesia to suit the need of the moment by watching the progress of the operation sufficiently to anticipate painful stimulation. This precaution will aid much in preventing delay and embarrassment from muscular reaction to pain during the course of the operation. For instance, in the case of laparotomy, a deeper plane of anesthesia is necessary for the incision of the skin, the opening of the peritoneum, exploration of the abdominal cavity for exposure of the organ needing correction, such as lifting the uterus from its pelvic bed, and the "walling off" of the intestines with gauze sponges, than will be required for surgery of the visceral organs alone. A long surgical procedure of this kind can be carried on satisfactorily under a plane of light anesthesia for the most part, provided the surgeon is reasonably gentle in his manipulations and the anesthetist is understandingly alert to the need of deepening the anesthesia in time to prevent reaction to the greater stimulation that the preliminary steps for closure of the peritoneum will involve.

The ability to adjust skillfully the degree of anesthesia to the need of the moment largely constitutes the "art of anesthesia," and the conscientious anesthetist will find it most stimulating and essential to master this art, for danger to the patient lies much more in the degree of concentration of the anesthetic drug in his body tissues than in the length of time the anesthesia is maintained.

Although, when properly given, ether is not difficult to breathe, the abnormal sensations of the first two or three minutes before consciousness is lost may be disturbing to some hypersensitive people, especially children. Also, if at some previous time the patient has suffered severe nausea following ether anesthesia, the odor of ether may cause repulsive recollection of the experience. Realizing these drawbacks, many anesthetists nowadays start the induction with an anesthetic of more rapid action: nitrous oxide, Vinethene, ethyl chloride, or intravenous pentothal. With any one of these drugs consciousness can be blotted out within one minute.

For the induction of anesthesia in a child, nitrous oxide has the advantage of being practically odorless. The procedure can be made very simple: a small rubber tube connected to a nitrous oxide tank or gas-oxygen machine is placed under the open-method ether mask, and the child is reassured that "there will be no smell to it." The gas flow must be very gentle, and unless oxygen is given with it, the face mask must be arranged so that plenty of air can circulate under it also. A few breaths of the gas dulls the sense of smell so well before consciousness is lost that the ether drop can then be started carefully without unpleasant reaction from the child. For a safe, smooth induction, any degree of cyanosis must be carefully avoided, but it is necessary to continue the flow of gas until a tolerance for a concentrated ether vapor has been gradually worked up. This tolerance can be established more quickly than when ether only is being used. When Vinethene or ethyl chloride are used for induction to ether, the drug is dropped slowly on the open mask, and since the effects are very similar to those of nitrous oxide, practically the same procedure is followed as for the gas. In either case, the procedure calls for practice and skill and, above all, the desire of the anesthetist for its satisfactory accomplishment.

The advantages of ether, when used in therapeutic dosage, are: (1) the potency is sufficient for the control of severe pain reflexes; (2) the planes of anesthesia are elastic and readily definable; (3) the margin of safety is relatively large; (4) little change is effected in the pulse and blood pressure; (5) it is relatively harmless to normal body tissues; and (6) the apparatus that is necessary for its effective use is very simple.

The disadvantages of ether are: (1) the vapor is irritating to the epithelium of the respiratory tract and causes increased secretion of saliva and mucus; (2) it is irritating to the lungs and kidneys, especially when inflammation is already present; (3) it causes much increase in blood sugar so its use is dangerous in the presence of diabetes unless the diabetic state is under control; (4) the incidence of postanesthetic nausea and vomiting is higher than with other anesthetic drugs; and (5) ether is inflammable.

CHLOROFORM ANESTHESIA

Chloroform, $CHCl_3$, is a clear, heavy liquid of sweetish odor with a high anesthetic potency. It has a boiling point of 61° C., much higher than that of ether, so the evaporation rate of chloroform is slower. This slow evaporation is an advantage under tropical conditions, but normal conditions present a need for precaution against toxic accumulation of the drug on the face mask in the event of shallow or erratic breathing.

The vapor of chloroform is relatively nonirritating to the air passages and can be breathed easily, so as a rule the induction of anesthesia is comfortable and rapid with little evidence of a stage of excitement. Unfortunately chloroform does not compare favorably with the other anesthetics in regard to safety, for it is a cardiac depressant, exerting a poisonous effect on the heart muscle. In serious accidents under chloroform anesthesia the heartbeat stops before, or at the moment of, cessation of respiration, and the possibility of resuscitating the patient is slight. Fatalities under chloroform are particularly shocking usually, for they are more likely to occur in the "good risk" patient, and during the induction stage before anesthesia is complete, rather than from an overdose of the drug. An explanation for this is given by Levy [2] on the principle that the toxic effect of chloroform causes pronounced cardiac irritability and hypersensitivity to stimulation of the sympathetic nervous system. He warns that an overflow of adrenalin from the adrenal glands, precipitated by excitement or fear, or by painful manipulation before the sensory nerves are paralyzed by the anesthetic, can throw the irritable heart into a state of ventricular fibrillation. Levy stresses the danger from surgical interference in too light a plane of anesthesia, both during the induction and recovery stages. Adrenalin or epinephrine medication in any form is definitely contraindicated during chloroform anesthesia.

Chloroform may also cause serious damage to the liver. Wesley Bourne [3] reported experimental studies giving proof that liver function is depressed for eight

[2] A. Goodman Levy, *Chloroform Anaesthesia*, p. 23.

[3] Wesley Bourne, Morris Bruger, and N. B. Dreyer. Effects of general anesthesia on function of the liver; the effects of Amytal and Avertin, separately, on the blood, its reaction, the carbon dioxide combining power, and the concentration; on body temperature; on the function of the liver; and on the rate of secretion and composition of the urine. Anesthesia and Analgesia, 10:85.

days by half an hour of chloroform anesthesia. He further states that following a two-hour anesthesia, the liver function is not fully restored for six weeks. "Delayed, or secondary, chloroform poisoning" is a condition of necrotic changes in the lobules of the liver, sometimes described as "fatty degeneration of the liver." The symptoms are those of acute acidosis, and the condition usually terminates fatally. As a means of safeguarding the liver against the damaging effects of anesthetic drugs, it is suggested that the patient be given generous quantities of sugar or glucose during the day preceding operation, when possible, in order to promote storage of liver glycogen.[4]

Technique for induction of chloroform anesthesia. Chloroform may be given by the open-drop method, by insufflation of the vapor with oxygen, or it may be added in very small proportion to nitrous oxide–oxygen in order to increase the efficiency of the gas when a potentially explosive anesthetic mixture is contraindicated. Chloroform is not inflammable. The open-drop method only will be described in detail.

The face mask for open-drop chloroform must be more open and less thickly covered than the ordinary ether mask, for chloroform is approximately ten times more potent than ether.[5] Chloroform is vesicant to the skin if evaporation is delayed, so the face should be lightly anointed with vaseline or cold cream before the mask is applied. The patient is reassured, and then the drug is started, drop by drop, increasing slowly, as a tolerance for the vapor is worked up, to a rate of about thirty drops per minute. As previously noted, special care must be taken to prevent fright and discomfort and to avoid accumulation of the

[4] M. D. Nosworthy, *The Theory and Practice of Anaesthesia,* p. 82.
[5] Arthur E. Guedel, *Inhalation Anesthesia. A Fundamental Guide,* p. 10.

drug on the mask during interruption of the rhythm of breathing. The stages of anesthesia, in general, are similar to those of ether, but they follow each other more quickly. The outstanding differences in effects from those of ether are that the face is more likely to be pale than flushed since there is decrease of pulse and blood pressure and the respiration is shallow and quiet rather than stimulated. Increased pallor, bradycardia, and shallow, sighing respiration are signs of dangerous overdosage. The maintenance of a patent airway and avoidance of cyanosis are essential for safety.

The advantages of chloroform are: (1) the vapor is nonirritating to the epithelium of the lungs and air passages; (2) it is noninflammable (but excessive heat will break it down into toxic phosgene gas); (3) the high boiling point makes its use practical in tropical atmospheres.

The disadvantages are: (1) the drug is a powerful circulatory depressant and cardiac irritant; (2) it sometimes causes serious toxic effects to the liver and other vital organs; and (3) the margin of safety is small.

ETHYL CHLORIDE

Ethyl chloride, C_2H_5Cl, with a boiling point of 12.5° C., is used both as a local and as a general anesthetic. In either of these ways its usefulness is limited to very brief procedures, one to three minutes. It is sold as a liquid in a metal or glass ampoule, which is fitted with a metal nozzle and finger-tip control valve. The liquid can be delivered in drops or in the form of a fine spray of vapor. General anesthesia can be induced with ethyl chloride either by the open-drop or the closed method. As the term implies, the drop method is given on a face mask that allows for much dilution of the drug with air. This is the more commonly used method. With the closed method, 1 to 5 cc. of the drug are sprayed as a vapor into a breathing bag immediately before the attached mask is applied to the patient's face. The pungency of the vapor will cause embarrassment of respiration by either method if the vapor is too concentrated, but this can be avoided of course. The patient loses consciousness in about thirty seconds on breathing the vapor. This is followed rapidly by flushing of the face, muscular rigidity, and stertor. As a rule, recovery after the mask is removed is equally rapid, but the margin of safety is very narrow.

Ethyl chloride may be used for a quick induction of ether anesthesia, and the early loss of consciousness gives tolerance for a higher initial concentration of ether vapor. However, any embarrassment of respiration, due to too strong a vapor of either drug, will defeat this purpose of a rapid induction.

Analgesia for dental treatment work is obtained with a weak ethyl chloride vapor, by means of a nasal apparatus fitted with a hand bulb of rubber that the patient controls. Should consciousness be lost, the power to squeeze the bulb in order to vaporize the drug goes with it, of course, and the patient quickly recovers.

The advantages of ethyl chloride are: (1) the rapid induction and recovery periods that the drug affords; (2) the drug and apparatus required for its effective use are compact and easily portable; and (3) a period of one to two and a half minutes of anesthesia, without cyanosis, after the mask is removed, allows for brief minor surgery without causing pain to the patient.

The disadvantages are: (1) the depth of anesthesia is not readily controllable; (2) the margin of safety is small; (3) stertor and muscular rigidity persist, with a tendency to laryngeal spasm; (4) postanesthetic nausea and vomiting are common with this drug; (5) the drug is a circulatory depressant and cardiac irritant; and (6) it is inflammable.

VINETHENE

Vinethene, or divinyl ether, $(C_2H_3)_2O$, is a colorless, volatile liquid anesthetic. The high potency of this drug, estimated to be seven times greater than ethyl ether, allows for such great dilution that its pungent odor is less disturbing to patients than is that of ether. Anesthesia is effected very rapidly, and the recovery period is equally short and comfortable with this drug. Owing to the speed of its action, the stages of anesthesia are not clearly defined as they are with diethyl ether. The very low boiling point, 28.3° C., and the high volatility of the drug increase the difficulties of maintaining an even plane of anesthesia. Experimental work on dogs has given evidence of liver damage following prolonged anesthesia with this drug; [6] in consequence, it is generally considered advisable to limit the time of anesthesia by open-drop method to one half hour. This drug is uniquely valuable as an agreeable anesthetic for very brief painful procedures, to ease and hasten induction of ether anesthesia, and to supplement nitrous oxide. The best guide for judging the depth of anesthesia and condition of the patient is the respiration, the excursion of which must always be kept adequate to allow for good exchange of oxygen and carbon dioxide. Muscular relaxation and control of pain reflexes, sufficient

[6] Samuel Goldschmidt, I. B. Ravdin, Baldwin Lucke, G. P. Muller, C. G. Johnston, and W. L. Ruigh. Divinyl ether: experimental and clinical studies. J. A. M. A., 102:21.

for many minor operative procedures, develop within two to three minutes, as soon as the conscious expression of the eyes is lost and before the eyelid reflex is totally abolished.

When given by the open-drop method, the face mask must be less thickly covered than is needed for ether. Vinethene should be dropped slowly on the mask and increased only moderately as the breathing tolerance is established. A high concentration of the vapor causes respiratory embarrassment and an excessive flow of saliva and mucus, and dangerous symptoms may quickly develop. Premedication with atropine to control secretions is indicated with this drug unless the anesthesia is to be very brief. Vinethene can also be given by the closed rebreathing method, in combination with oxygen and the gaseous anesthetics. Frequently it is used for a quick induction of ether anesthesia.

The advantages of the drug are: (1) the induction and recovery periods are brief; (2) postanesthetic nausea and vomiting are very rare with the use of this drug; (3) a minimum of apparatus is necessary for effective results; and (4) its high potency is helpful for the induction of ether anesthesia and to supplement nitrous oxide–oxygen.

The disadvantages are: (1) the plane of anesthesia is not readily definable; (2) some liver damage may be caused by prolonged anesthesia with this drug; and (3) in combination with air or oxygen, it is inflammable.

Chapter 7

GASEOUS ANESTHETICS: NITROUS OXIDE, ETHYLENE, CYCLOPROPANE

SOME knowledge, in detail, of the apparatus involved in the use of the gaseous anesthetics is essential for a general understanding of the subject as a whole.

The gases commonly used for the purpose of surgical anesthesia at the present time are the anesthetics, nitrous oxide, ethylene, cyclopropane; and the adjuvants, oxygen, carbon dioxide, and helium. These gases are marketed, under great compression, in heavy steel cylinders that are fitted with a valve head and key, *i.e.*, hand wrench, for attachment of the cylinder and release of the gas to the gas-oxygen machine. The machine provides for the accurate proportioning and mixing of the gases for administration to the patient.

The cylinders of each gas are of several sizes designated by letters, A through G. The sizes D, E, and G are most commonly used on hospital apparatus. The cost per gallon of gas decreases in proportion to the increase in the size of the cylinder; but in order to use the large G cylinder, a truck of special construction with a connecting metal tubing is necessary. In some large hospitals where a great deal of "gas anesthesia" is used, the gases are piped into the operating room under reduced pressure from a main supply base.

The initial pressure of each gas is uniform for all sizes of cylinders. But this pressure varies considerably for the different gases and depends upon the molecular weight and response to compression of the individual gas. The pressure range is from 75 lbs. per square inch for cyclopropane to 2000 lbs. per square inch for oxygen.

For control of this great force, all gas machines are fitted with a finely adjusted valve at each inlet. This control valve must be closed before the cylinder is opened; this is essential in order to prevent the danger of personal injury as well as damage to the gas-oxygen machine. Within recent years neglect of this seemingly small detail was responsible for the death of an anesthetist who was critically injured by flying glass when the machine was demolished by an oxygen-pressure explosion.

Identification of the gas content of cylinders is made readily apparent by a uniform color system agreed upon by the anesthetic-gas distributors of America and approved by the United States Bureau of Standards. An individual color is assigned to each gas regardless of the size of the cylinder. In addition, a distinctive label is pasted on each cylinder giving the name of the gas, weight of cylinder and of contents, etc. Manufacturers of the gas-oxygen machine also have done their best to safeguard against mistaken identity of the gases by a similar distinct system of labeling. Occasionally, however, tragic accidents happen from one of the anesthetic gases being mistakenly used in place of vital oxygen. Such an accident is inexcusable, for with proper precaution it is always preventable.

The usual sequence of such an accident is that cylinders of oxygen and nitrous oxide emptied on a previous case have been replaced by full cylinders, but they have been accidentally transposed on the machine. This has remained unnoticed. Many gas-oxygen machines are fitted with duplicate cylinders of each gas, and for the next patient the anesthetist, while using the original oxygen outlet, happens to use the duplicate outlet for the anesthetic gas. Very soon the patient's color proclaims the pressing need for oxygen, and the anesthetist opens the emergency valve and too late realizes the patient has been asphyxiated by a blast of nitrous oxide from the transposed cylinder. (The oxygen valve is equipped with an emergency valve in addition to the control valve, by which oxygen can be added in large quantity should such a need arise.) No one is wholly infallible, and too much emphasis cannot be put on the need for constant vigilance for the avoidance of such tragic accidents. Before starting the anesthesia, a thorough check must be made by the anesthetist for assurance that the entire equipment is identified correctly. This is an essential rule for the correct dispensing of all medication.

At the close of each case, the face mask, breathing tubes, and bag need to be thoroughly washed with liquid soap and running warm water. When this is done thoroughly, it is sufficient cleansing of these articles for the routine case; but additional boiling, or soaking in an antiseptic solution, is indicated when they have been used for a patient suffering from any form of infectious respiratory disease. Boiling is the ideal way to disinfect rubber articles, but rubber cuffs of all descriptions must be deflated before immersion in boiling water to prevent expansion of the enclosed air and consequent rupture of the cuff. Celluloid attachments, facepiece, etc., should be sterilized in the antiseptic solution since they are ruined by boiling. The disagreeable odor left on rubber by soaking in a solution of the phenol derivatives makes this group of antiseptics undesirable for rubber equipment.

Another advisable precaution in cleaning the machine between cases is the rinsing out of pungent odors of ether and ethylene, which cling to all the tubes and passages. This can be effected by a brisk flow of the practically odorless oxygen or nitrous oxide for a few moments. This practice is essential if the anesthetist plans to coax a patient to accept nitrous oxide–oxygen anesthesia readily with the promise "there is no smell to it."

Nitrous oxide being a "weak anesthetic," *i.e.*, effective for the average patient only when given in very high concentration, presented several problems to be solved before it attained its present high status in surgical anesthesia. The danger of the complication of anoxia, which was the most important problem, was solved by the substitution of oxygen for air as the diluent. Another problem was the risk of overventilation, profound loss of carbon dioxide from the system. This is caused by the stimulation of breathing due to inefficient control of pain reflexes by an anesthetic of low potency. This problem was solved by sedative premedication and the inclusion of a breathing bag between the cylinder outlet and the face mask. The breathing bag allowed the patient to rebreathe a portion of his exhaled carbon dioxide and in this way to circumvent apnea caused by overventilation. An exhaling valve provided a means of escape for excess carbon dioxide. Of course, much of the anesthetic gas was lost also through the exhaling valve, and a continuous flow of gas from the cylinder was necessary in order to replace this loss as well as to replace oxygen used in the body metabolism.

The publication in 1926 by Dr. Ralph M. Waters[1] of the encouraging results he obtained by filtering the carbon dioxide from the exhaled gases, in order that they might be effectively rebreathed for prolonged periods, led to the present-day general adoption of the method of closed rebreathing. In addition to great economy in the use of the gases, the method provides for adequate control of the respiration by control of its normal stimulant, carbon dioxide, as the filter can be turned in and out of the circuit at will. It also affords an excellent means of artificial respiration in case of need.

The gases are filtered by being passed through a chamber filled with soda-lime (sodium and calcium hydroxide), which has an affinity only for the carbon dioxide in the exhaled mixture. The carbon dioxide reacts with the hydroxide to form a carbonate.

Two types of filter chambers are available: the original "Waters' to-and-fro," and the "circle" apparatus. With the former, as the term implies, the patient breathes both in and out through the soda-lime. The filter chamber is inserted between the face mask and breathing bag and in direct contact with them; no valves are involved. With the circle type of apparatus, the filter chamber and breathing bag are attached to the gas-oxygen machine, and connection with the face mask is made by means of two large-caliber, corrugated-rubber tubes. Sensitive valves are interposed so that the exhaled gas mixture can be passed through the filter and on into the bag, from which the purified gases are returned direct to the

[1] Ralph M. Waters. Advantages and technic of carbon dioxide filtration with inhalation anesthesia. Anesth. and Analg., 5:160.

face mask to be rebreathed by the patient, so completing the circle.

The to-and-fro apparatus is simpler and less expensive than the circle type, is readily portable and interchangeable from one gas machine to another, and the "dead space" is decreased by the absence of long breathing tubes. This last feature is of special value with the shallow, rapid breathing common in young children and febrile patients. The special advantage of the circle apparatus is that the weight of the canister of soda-lime is borne by the gas-oxygen machine, so there is less drag of the face mask to impede its leakproof adjustment to the patient's face. However, this desirable tight adjustment can usually be maintained with the to-and-fro apparatus if a little ingenuity is exercised in the support of the canister. In skilled practice, the omission of a by-pass valve seldom presents a serious problem.

Success with either method depends upon the use of a high grade of soda-lime, with granules of 4 to 8 mesh. In recent years another absorbent, Baralyme (barium and calcium hydroxide), has become available. The material is compressed into uniform hard pellets that have the advantage over soda-lime granules of greater stability in form, thus diminishing the danger of the patient's inhaling dust from the absorbent.

The duration of absorbent efficiency of both of these agents depends, of course, upon the amount of carbon dioxide that is being excreted by the patient. This, in turn, depends upon the age, size, and metabolic rate of the patient. Any condition that increases the metabolism causes an increase in the consumption of oxygen and the production of carbon dioxide in the body system. Normally, the rate of metabolism is highest in extreme youth, decreasing slowly in adults. But throughout life, the rate is increased in varying degree by such stimulating factors as fever, certain forms of toxicosis, pain, fear, and emotional excitement of all kinds. In the normal case, an average of five to seven hours of absorbent efficiency may be expected from each charge of the filter.

As the filter efficiency becomes exhausted, the clinical signs of accumulating carbon dioxide are clearly evidenced by marked stimulation of breathing and increase in systolic pressure. The pulse rate, usually, is also increased if the stimulation is prolonged. Most of the modern gas-oxygen machines allow for rapid change to a fresh charge of the absorbent, with little interference in the smoothness of the anesthesia.

There are several types of gas-oxygen apparatus bearing trade names on the market, and equally good results can be obtained with them all. Requisite for this, of course, are familiarity with the machine and skill on the part of the anesthetist. Fundamental components for the machines are: a means for the accurate measurement and mixing of one or more anesthetic gases and oxygen, a reservoir for ether, breathing bag, tubes, and face mask. Provision should be made for duplicate cylinders of oxygen equipped with valves for both fine and coarse control of oxygen flow so that an abundant supply of oxygen is readily available in case of emergency.

NITROUS OXIDE

Nitrous oxide gas, N_2O, is very soluble in the blood and is carried by the plasma in simple solution.[2] After passing through the body, it is excreted in its original gaseous form by the lungs. When the gas is breathed undiluted, consciousness is lost within twenty to

[2] Goodman and Gilman, *op. cit.*, p. 81.

thirty seconds, and a state of asphyxia rapidly develops if breathing of the gas continues. However, if the gas flow is stopped, a state of analgesia persists for one to two minutes before full consciousness is reestablished, a sufficient time for the rapid extraction of one or a few teeth. For many years before nitrous oxide was accepted as an anesthetic for surgery, the following simple method of gas anesthesia was widely used in the dental office. The patient's mouth was opened, inspected, and a prop inserted between the upper and lower teeth before the face mask was applied—a necessary precaution against extreme difficulty in opening the mouth when the jaw muscles became rigid from oxygen insufficiency. As soon as the patient lost consciousness, the face mask was thrown aside and the work commenced. The number of teeth that could be extracted without pain for the patient depended chiefly upon the skillful speed of the dentist. The appearance of the patient meanwhile was usually sufficiently alarming to discourage his being subjected to a repetition of the ordeal on the same day, even though his recovery was immediate and uncomplicated. The forced brevity of the experience probably accounts for the fact that serious accidents very seldom complicated this precarious technique of dental anesthesia.

The addition of oxygen to the anesthetic gas and the use of a nasal inhaler have eliminated the need for speed in dental surgery, and extensive procedures can now be safely undertaken.

Nitrous oxide analgesia. Without loss of consciousness nitrous oxide analgesia is practiced for prolonged dental treatments by means of a small inhaler made to fit over the nose only, which is held in place by a strap passed around the patient's head. The gas, much diluted with air or oxygen, is delivered through a connecting tube to which is attached a simple rubber bulb, or spraying valve, that the patient controls with his hand. Should the stage of analgesia begin to develop into true anesthesia, the patient's pressure on the valve relaxes, automatically shutting off the flow of gas, and the patient recovers consciousness. A similar method of analgesia can be used effectively in obstetric practice for the relief of the intermittent pain of the late first and early second stages of labor when an anesthetist is not immediately available. Analgesia alone can be relied upon for these cases when the proportion of nitrous oxide in the mixture is not allowed to exceed 50 per cent. A face mask large enough to cover the patient's nose and mouth is desirable, but in order that it will fall off if the patient goes to sleep, it must not be in any way fastened to the face.

Nitrous oxide–oxygen surgical anesthesia. This gas combination is weak in its power to control the reflexes that result in muscular movements and rigidity caused by the pain of surgery. It is unsatisfactory as a surgical anesthetic for the average case unless it is supported by adequate premedication and unless the dilution of the anesthetic gas is limited to 20 per cent —the proportion of vital oxygen in the atmosphere we normally breathe.

Nitrous oxide is considered to be the least toxic of all the inhalation anesthetics and is noninflammable. Consequently, it is quite worth while for the anesthetist to make the effort necessary to become expert in the use of nitrous oxide–oxygen. Its possibilities as a surgical anesthetic are considerably wider than is generally appreciated. The technique calls for careful attention to detail in several ways, as follows: (1) an endeavor to gain the patient's confidence and co-operation and to allay apprehension; (2) adequate narcotic premedication for relief of pain; (3) rinsing out of all diluting air from the lungs and tissues of the body; (4) avoidance of painful manipulation during the induction period; and (5) gentle surgical handling of the body tissues throughout the operation—a strong plea for this anesthesia, for it is a well-recognized fact that an important contributing cause of surgical shock is trauma to tissues.

Although undiluted nitrous oxide is practically odorless, nonirritating, not at all difficult to breathe, and unconsciousness is rapidly induced, the sensations experienced may be definitely unpleasant. Sometimes these sensations have been described as a feeling of "being forcibly blown into a tunnel," or of one's head "bursting open." These discomforts are caused by the sudden deprivation of oxygen and can be entirely prevented if about 10 per cent of oxygen is used with the nitrous oxide from the start of the induction and loss of consciousness will be delayed for only a minute or so. The patient's color must be watched carefully, and as soon as it becomes slightly dusky, or bluish, the oxygen should be increased to the minimum safe maintenance proportion of 20 per cent. In the case of small children and the "poor risk" type of patient, it is wise to use 20 per cent of oxygen in the mixture from the start and a larger proportion during the maintenance stage.

From long experience in the use of nitrous oxide-oxygen anesthesia, for major as well as for minor surgery, the author is convinced that nothing is gained by reducing the proportion of oxygen during the maintenance stage below the 20 per cent of atmospheric oxygen, and, furthermore, that any degree of oxygen deficiency induces a corresponding degree of muscular rigidity or spasm. A demand from the surgeon for deepening the plane of anesthesia is prompted by the need for adequate muscular relaxation, and the only safe and sensible thing to do in an effort to satisfy this need is to supplement the weak anesthetic gas with some more potent drug. Usually the addition of a small amount of the potent drug at infrequent intervals will prove sufficiently effective, and this will cause little untoward complication of the recovery period.

The maintenance of a clear airway is essential throughout the period of unconsciousness. To prevent the relaxed, or congested, tongue from blocking the pharynx, it may be necessary to insert an oral or nasal airway tube. (Figure 4, Chapter V.) These tubes are curved and of sufficient length to pass into the pharynx at the base of the tongue. The tube should be lubricated and inserted carefully. An oral tube is more satisfactory when the tissues are relaxed and the mouth easily opened as, despite care to avoid it, troublesome bleeding from sensitive nasal mucosa may be caused by the passage of a nasal tube. However, if the obstruction is caused by congestion, the rigidity of the jaw makes opening of the mouth so difficult that the nasal tube is indicated. Under these conditions the result when the nasal tube reaches the pharynx is gratifyingly spectacular.

Induction of nitrous oxide–oxygen anesthesia. Immediately before the patient is taken into the room where the anesthesia is to be started, the anesthetist should make a final inspection of the gas-oxygen machine to make sure that it is in good order, that no gas cylinder is empty or misplaced, and that ether is readily available should it be needed for the control of an active stage of excitement. The gas-control valve for both nitrous oxide and oxygen should then be closed and the cylinder valves opened. The breathing bag is then inflated about three quarters full, with a measured proportion of each gas to allow for at least 10 per cent oxygen. (Most gas machines are equipped with an obturation valve so that the breathing bag can be filled beforehand without loss of gas.) When all is in readiness, the patient is reassured, and a final inspection made of his mouth for loose teeth, removable dentures, etc. The face mask is then gently applied to cover the nose and mouth, and the obturation valve is opened to release the gas mixture from the breathing bag. The patient meanwhile is instructed to breathe normally. The exhaling valve is open at this time, and a flow of the two gases is started in order to replace that which is being intentionally lost through this valve.

As the patient becomes drowsy, the mask is securely fastened onto the face. The oxygen proportion is increased sufficiently to keep the patient's color normal, and if a stage of active excitement is induced, a little ether vapor should be added to the anesthetic mixture. It should be remembered that though the patient is unconscious, a tolerance for ether vapor must be worked up gradually in order to prevent embarrassment of respiration. As soon as surgical anesthesia is established, the ether can be stopped and from then on added intermittently when and if indicated.

If the machine is not equipped with a carbon dioxide filter chamber, the flow of both gases in correct proportion must continue throughout the anesthesia in order to allow for the spillage of excess carbon dioxide. But when the filter is to be used, the object of the open exhaling valve and continuous flow of the anesthetic gas is to get rid of nitrogen from the patient's lungs, which otherwise would too greatly dilute the nitrous oxide. Depending upon the character of the respiration, five to eight minutes are needed for this purpose, after which the breathing bag is quickly emptied by manual pressure and refilled with the maintenance proportions of the two gases. Then the exhaling valve is closed, the nitrous oxide flow stopped, and the filter turned into the circuit. The flow of oxygen, adjusted to the probable metabolic need of the individual patient, must continue throughout the time of anesthesia in order to replace the oxygen used in the metabolic processes. A flow of oxygen at the rate of about 350 cc. per minute is satisfactory for the average adult.

A leakproof adjustment of the face mask is necessary if the rebreathing is to be complete, but precaution must be taken against the danger of injury to the face due to pulling the straps of the inhaler too tight. Frequent gentle massage of the face, especially around the prominence of the cheekbones, stimulates the circulation of the area and thus helps in the prevention of pressure sores. When a continuous slight leakage cannot be safely prevented, the bag pressure should be maintained by a compensating small continuous flow of the anesthetic gas with sufficient additional oxygen to keep up the correct proportions. The breathing bag should be emptied and refilled with fresh gases at about fifteen-minute intervals during the first hour of anesthesia in order to get rid of traces of diluting nitrogen that are being gradually freed from the body tissues.

With the gaseous anesthetics the stages of anesthesia follow each other too rapidily for detailed identification other than loss of consciousness, evidence of excitement, and the relaxation of normal sleep. During the maintenance stage, when the patient's color is normal, the eye signs that are helpful with ether anesthesia are absent. The pupils as a rule remain contracted, and when the anesthetic is limited to nitrous oxide–oxygen, a slow oscillation of the eyeball commonly persists throughout the anesthesia.

The cardinal rule to follow with nitrous oxide–oxygen anesthesia is to keep the patient's color normal at all times because anoxia, oxygen deficiency, constitutes the sole danger. To prevent anoxia, in addition to an adequate proportion of oxygen in the breathing bag, a clear airway, free from mucus or any form of obstruction, is essential. Color changes are not as clearly evident in patients who are pale and anemic, and this type of patient is also hypersensitive to medication and is easily anesthetized. It is, therefore, well to keep more than the usual 20 per cent of oxygen in the breathing bag during the maintenance stage with such cases. One can always resort to the addition of a small quantity of a more potent drug if necessary for control of inconvenient reaction to pain. A proportion as high as 50 per cent oxygen with nitrous oxide sometimes will provide adequate anesthesia for a patient in shock.

ETHYLENE-OXYGEN

Ethylene (C_2H_4) is a highly volatile gas with a specific gravity slightly less than that of air. It has a pungent, somewhat disagreeable odor, but the gas is nonirritating, and on breathing it, one's sense of smell is so quickly abolished that this odor is of no great importance. The anesthetic potency of ethylene is a little higher than the potency of nitrous oxide. Guedel ranks the gas as 10 per cent higher in potency than nitrous oxide.[3] Consequently, ethylene-oxygen is rather more effective in controlling the reflexes of pain and a smooth anesthesia can be maintained more easily.

[3] Arthur E. Guedel, *Inhalation Anesthesia. A Fundamental Guide*, p. 60.

The technique for the administration of ethylene-oxygen anesthesia is identical with that described for nitrous oxide–oxygen. The significant difference between these two gases is the fact that ethylene is potentially explosive and precautions must be taken to avoid this danger. The use of this gas in the presence of an open flame or sparking electric apparatus is unjustifiable. It is essential to bear in mind also that a potentially explosive combination is formed when ether is added to nitrous oxide–oxygen.

The importance of preventing anoxia of any degree and of keeping the color of the blood consistently normal should be emphasized equally for ethylene-oxygen and for nitrous oxide–oxygen anesthesia.

CYCLOPROPANE-OXYGEN ANESTHESIA

Cyclopropane (C_3H_6) is a volatile gas, considerably heavier than air, with a slightly pungent not unpleasant odor. It is readily inflammable when mixed with oxygen or air. Unlike nitrous oxide and ethylene, this gas is of high anesthetic potency. Guedel classes cyclopropane with the volatile liquid anesthetics as having a potency of 100 per cent,[4] *i.e.,* sufficient for all planes of surgical anesthesia.

In rough calculation, when oxygen alone is used as the diluting agent, the proportions are the reverse of those needed for the weak anesthetic gases. An average of 20 per cent cyclopropane and 80 per cent oxygen is the rule. As with any powerful drug, however, these proportions must be varied and adjusted carefully to accord with the general condition of the individual patient and the type and quantity of sedative premedication that he has been given.

Cyclopropane in anesthetic dosage has little toxic

[4] *Ibid.*

effect on the body tissues as a whole. This fact and the possibility of using an abundance of oxygen with it make this anesthetic especially valuable for the very sick patient and for the patient whose circulation or ventilatory capacity is seriously impaired. Anesthesia is induced quickly and comfortably with cyclopropane-oxygen and rarely is it complicated by a "stage of excitement." As a rule the recovery period is short and equally uneventful. But the anesthetist who is unfamiliar with cyclopropane may have difficulty in defining the planes of anesthesia during the maintenance stage. Both cyclopropane and a high proportion of oxygen tend to depress the respiration. Therefore, with this combination of gases the breathing is quiet and shallow; yet the patient's color remains excellent on account of the excess oxygen. Neither can the depth of anesthesia be defined by the appearance of the eyes, especially when morphine has been given beforehand, for the pupils rarely dilate unless a profound anoxia has been allowed to develop. Fortunately, in the event of an overdose of cyclopropane, the respiration ceases before the heart action stops, and the experienced anesthetist can restore normal breathing by inflating the lungs a few times with oxygen. This is done by intermittent manual pressure on the breathing bag after it has been quickly emptied of the anesthetic and refilled with oxygen. Of course, it must be ascertained that there is no obstruction of the patient's airway.

Cyclopropane anesthesia may cause cardiac arrhythmia at times, but this complication can be quickly corrected by further dilution of the anesthetic with oxygen. Consequently, a developing arrhythmia should be recognized as a sign that the percentage of cyclopropane has been increased beyond the level of tolerance for the drug that is safe for that individual patient. For correction of the arrhythmia, dilution of the anesthetic gas should proceed gradually, and it should be stopped as soon as the pulse resumes normal rhythm, otherwise the anesthesia may become too inefficient for the surgeon to proceed with the operation. A little ether vapor can be added to the gases if it becomes necessary to deepen the plane of anesthesia beyond the point made possible by the patient's tolerance for cyclopropane.

The reason for this complicating arrhythmia remains a matter of controversy, but it is probably a wise precaution to avoid the use of epinephrine in any form during cyclopropane anesthesia, in case this drug might add to the cardiac irritability.

Many patients suffering from cardiac disease, showing marked arrhythmia, have been successfully anesthetized with cyclopropane-oxygen, and if the condition of the patient is sufficiently good to warrant the use of general anesthesia, this gas is not necessarily contraindicated,[5] for it affords several advantages as an anesthetic. Special care should be taken, however, to avoid any increase of pulse irregularity, and high concentrations of the gas should not be used.

As a general rule the pulse rate is moderately slowed during cyclopropane anesthesia. A sudden marked decrease or increase of the pulse rate, or an arrhythmia that cannot be otherwise accounted for, should be accepted as signs that the concentration of cyclopropane in the anesthetic atmosphere is too high for that individual patient, and reduction of the concentration by addition of oxygen is indicated.

Although the patient's blood pressure has been sustained remarkably well throughout a prolonged cyclopropane anesthesia for major surgery, it may be found

[5] Ralph M. Waters. Cyclopropane—a personal evaluation. Surgery, 18:28.

to have fallen to a seriously low level soon after he is returned to the ward. This phenomenon is explained on the principle that the shallow breathing typical of this anesthesia reduces respiratory exchange and consequently a high level of carbon dioxide accrues in the blood stream. The superabundance of carbon dioxide has a stimulating effect on the circulation, and the blood pressure is sustained until the excess carbon dioxide is washed out of the system. This elimination is effected during the patient's waking moments when, in response to pain and restlessness, the respiration is stimulated. With the loss of carbon dioxide the blood pressure falls, and a more accurate picture of the patient's circulatory condition becomes evident.[6]

When, from the severity of the operation, some degree of surgical shock is to be expected, this condition may be revealed earlier if nitrous oxide–oxygen is substituted for the cyclopropane anesthesia ten minutes or so before the operation is completed. Restorative measures can then be started before the patient is returned to bed, should this precaution seem to be advisable, for a state of shock may be seriously increased by the handling that is involved in the removal of the patient from the operating table to the bed and ward.

Cyclopropane-oxygen may be used for anesthesia either in single combination or mixed with helium or air. Cyclopropane may play the dominating role in either a nitrous oxide–oxygen or ethylene-oxygen anesthesia, or its powerful anesthetic properties can be employed in the same way as the volatile liquid anesthetics—to supplement these weak anesthetic

[6] Robert C. Dripps. The immediate decrease in blood pressure seen at conclusion of cyclopropane anesthesia; "Cyclopropane Shock." Anesthesiology, 8:15.

gases. This range in flexibility of cyclopropane as an anesthetic supports the reasons that have been advanced against routinely limiting dilution of this potent anesthetic gas to oxygen only. The following reasons have been advanced: (1) less of the more toxic cyclopropane will be required when supplemented by one of the weak anesthetic gases (the more potent the drug the higher the ratio of toxicity); (2) a high proportion of oxygen in the gas mixture increases the hazard of explosion; [7] (3) all of the inhalation anesthetics and oxygen are absorbed very rapidly from the lungs, but the inert gases, nitrogen and helium, are slowly absorbed.[8] The addition of nitrogen or helium to the anesthetic mixture therefore safeguards against the development of a localized atelectasis if bronchial passages should become plugged temporarily with mucus; (4) excess oxygen in the blood may interfere with the mobility of carbon dioxide in the tissues of the body and with the acid-base balance; [9] (5) although a generous supply of oxygen increases the safety of all anesthesias, the body can use only a limited quantity and cannot store oxygen; [10] and (6) the body is adjusted to the quantity of oxygen in the atmosphere at sea level, which is approximately 20 per cent, and a marked increase above this over several hours of time may have toxic effects on the lung epithelium.[11]

It is impracticable to administer cyclopropane-oxygen for surgical anesthesia except by the method of closed rebreathing as the initial cost of this potent

[7] Ralph M. Waters. Cyclopropane—a personal evaluation. Surgery, 18:28.

[8] Pol N. Coryllos and G. L. Birnbaum. Studies in pulmonary gas absorption and bronchial obstuction. Part 3: A theory of gas absorption and atelectasis. Am. J. M. Sc., 183:355.

[9] Samson Wright, *Applied Physiology*, p. 405.

[10] Henry K. Beecher, *The Physiology of Anesthesia*, p. 124.

[11] *Ibid.*, p. 126.

anesthetic gas is high. Cyclopropane anesthesia by this method, however, is not expensive, despite the high cost of the gas, for the exhaling valve can remain closed throughout the operation and there is little waste of gas. This is in contrast to the technique required for the weak anesthetics, nitrous oxide and ethylene, when much gas is wasted in order to eliminate the diluting nitrogen from the body tissues. In addition to the saving of gas, the closed exhaling valve provides for the rebreathing of exhaled carbon dioxide to increase respiratory excursion and so hasten the induction of anesthesia, therefore the filter system should be cut out until the surgical stage of anesthesia is reached.

The following technique for the administration of cyclopropane-oxygen anesthesia is similar to the method originally described by Dr. Waters in 1934.[12] Over the years it has proved satisfactory for the average patient. The breathing bag is inflated two thirds full with oxygen for adequate dilution of cyclopropane from the start. The inhaler is then gently applied over the patient's nose and mouth and the obturator valve is opened. The control valves of the cyclopropane and oxygen are opened and set at a flow of 500 cc. of each gas; meanwhile the patient is instructed to breathe regularly and reasonably deeply. There is slight odor to the gas in this great dilution, and it is nonirritating to the air passages. After a few breaths of the gas the patient's sensitivity as a whole will be sufficiently dulled so that the inhaler strap can be tightened and fastened without causing discomfort. When the breathing bag is full, the flow of oxygen is reduced to the approximate quantity that

[12] J. A. Stiles, W. B. Neff, E. A. Rovenstine, and R. M. Waters. Cyclopropane as an anesthetic agent: a preliminary clinical report. Anesth. & Analg., 13:56.

is being consumed in the metabolic processes of the individual patient, and this replacement of oxygen continues throughout the operation. The quantity of cyclopropane that will be needed in order to induce and maintain surgical anesthesia will also vary with individual cases, and the 500 cc. flow of this gas is continued for one to three minutes accordingly. The filter is now turned into the circuit.

Cyclopropane anesthesia culminates rather slowly, and as soon as the patient is unconscious and quiet, the flow of the gas should be stopped temporarily for the anesthesia will continue to deepen somewhat. This precaution is necessary in order to avoid the danger of seriously depressing the occasional patient who is hypersensitive to anesthetic drugs.

For the maintenance of an even plane of anesthesia, the addition of a small quantity of cyclopropane will be required at intervals, though a leakproof system may seem to have been effected and the filter is functioning properly. This additional gas is needed to compensate for dilution of the rebreathed vapor with nitrogen, which is being gradually freed from the body tissues, and for the loss of cyclopropane by evaporation from cut surfaces and, possibly, by permeation of this gas through the rubber walls of the breathing bag.

In contrast to the strict anesthetic limitations of nitrous oxide and ethylene, the plane of surgical anesthesia can be adjusted with this highly potent gas to suit the need of the moment without risk of the complication of anoxia. Usually, muscular relaxation under cyclopropane anesthesia is good but not invariably as good as is obtainable under ether anesthesia. Ether vapor combines well with cyclopropane and may be added to the rebreathed anesthetic mixture whenever necessary.

Helium can be used as a supplement to oxygen for the dilution of cyclopropane when a very high proportion of oxygen is not especially indicated by the patient's general condition. Combination of these gases offers two distinct advantages: (1) reduction of the proportion of oxygen reduces the hazard of explosion; and (2) the lighter anesthetic atmosphere obtained by the replacement of a quantity of oxygen, which has an atomic weight of 16, with helium, having an atomic weight of 4, lessens resistance to breathing. This lighter atmosphere is especially helpful sometimes in overcoming stridor that may result from sudden painful manipulation while the anesthesia is insufficiently deep.

The technique for the cyclopropane-helium-oxygen procedure is similar to the one that has been given for cyclopropane-oxygen except that the initial two-thirds filling of the breathing bag is done with helium and 25 per cent oxygen. Helium is added during the maintenance stage only if the bag has to be refilled. The proportion of oxygen in the mixture of gases should never be less than 25 per cent.

Nitrous oxide or ethylene, with 25 per cent oxygen, makes a good basal anesthesia for cyclopropane when a superabundance of oxygen is unnecessary. In comparison to cyclopropane-oxygen in single combination, the advantages afforded by the basal group are as follows: (1) there is less depression of respiration and, consequently, less abnormal stimulation of the circulation by retained carbon dioxide in the system; (2) less of the more toxic gas will be required when it is supplemented with another anesthetic; and (3) depressive overdosage may be detected earlier by eye and color signs than when the percentage of oxygen in the rebreathed atmosphere is very high.

The technique to be followed is the same as for cyclopropane-oxygen with the exception that one of the weak anesthetic gases and 25 per cent of oxygen are used for the initial filling of the breathing bag. The basal anesthesia can be made more effective by partially rinsing out the air from the lungs and air passages with it before the cyclopropane is added to the gas mixture. This is done by continuing the flow of nitrous oxide (or ethylene) and oxygen for two or three minutes with the exhaling valve open when the anesthesia is first started. With cyclopropane-oxygen anesthesia some anesthetists prefer to keep up a continuous flow of cyclopropane during the maintenance stage at a rate of about 20 to 30 cc. per minute for the average case. It has been reported that the continuous-flow method is usually essential for smooth maintenance anesthesia when the patient is an infant or small child. The high metabolic rate, rapid pulse, and respiration, and the small body area that can serve as storage reservoir for the anesthetic are handicaps these patients present towards a smooth anesthesia.

Whenever the anesthesia has been maintained entirely by any one or combination of the gaseous anesthetics, it should not be discontinued until the surgical procedure has been fully completed, including dressing of the wound. The patient recovers consciousness quickly after the mask has been removed, and he may suffer much discomfort and pain in being lifted from the operating table to the stretcher or bed. Unfortunately the tired "surgical team," adjusted to working over an unconscious patient, seldom realize that consciousness has returned so quickly and are not sufficiently gentle in this last necessary handling of their patient.

Chapter 8

AVERTIN

TRIBROMETHYLALCOHOL, a white crystalline salt synthetized by the German chemists Willstaetter and Duisberg and first used as a general anesthetic in Germany in 1926, was introduced into the United States two years later in liquid form, combined with amylene hydrate, under the trade name Avertin.

Each cc. of the fluid contains one gram of the salt. The dose, carefully adjusted to the individual patient, is administered slowly by rectal injection as a 2½-per-cent solution in distilled water. The drug is rapidly separated from the solution into the blood stream through the intestinal mucosa; consequently, withdrawal of a portion of the fluid subsequent to the injection may be ineffective in reducing the dose, should such prove desirable.

Avertin is depressant to the central nervous system and unconsciousness is induced by it very comfortably and quickly; but the superficial nerve endings are little affected and large doses of the drug are necessary to prevent muscle reaction to pain. It is generally accepted that Avertin should be used only as a basal anesthetic to be supplemented, as necessary, by a more controllable method for complete surgical anesthesia.

This is because of the well-recognized variation in tolerance for anesthetic drugs and the fact that any fairly long-acting drug given en masse in sufficient amount to obtain the desired effect cannot be kept under control with the safety possible by the method of inhalation or of intravenous injection.

Conservative small dosage of Avertin is effective in completely abating excitement and fear. In addition to this psychic advantage, basal anesthesia increases the efficiency of the so-called "weak" gaseous anesthetics, nitrous oxide and ethylene. It also greatly decreases the quantity of ether, or other anesthetic of high potency, that would otherwise be required to produce satisfactory surgical anesthesia.

Unlike the common inhalation anesthetics, Avertin undergoes a definite chemical change in the body. It is detoxicated in the liver by combination with glycuronic acid, in which form it is excreted by the kidneys. Elimination is affected by the rate of the body metabolism. Therefore, conditions of abnormally low metabolic rate, or impeded liver function, are contraindications to the use of Avertin. Conversely, tolerance for the drug is increased in the presence of a high rate of metabolism.

Usually, with this drug, there is some initial fall of blood pressure, the degree depending upon the speed of absorption and the size of the dose. Under relatively normal conditions, even when the fall of blood pressure is marked, there are no accompanying signs of shock, and the pressure readily responds favorably to some simple form of physical stimulation such as preparation of the surgical field, or the start of the supplementary anesthetic—with plenty of oxygen and the careful maintenance of a clear airway. Greater conservatism in dosage is indicated for the patient with marked hypertension, or the fall of blood pressure will be more profound. The drug is definitely contraindicated for the patient who is in a state of shock.

A convenient scale of dosage is provided with each package of fluid Avertin, computed on the basis of a maximum dose of 100 mgm. of the drug per kilogram of body weight. The scale ranges downward, in variations of 10, to the dose of 60 mgm. per kilogram, with the quantity of water calculated for each dose required, to make the usual 2½-per-cent solution. It is so arranged that the dose may be readily adjusted according to the state of health, or debility, and special needs of the individual patient. Included in the directions for preparation of the solution is the warning that obesity lessens the tolerance of an individual for this drug. A maximum limit is set to the quantity that should not be exceeded as the initial dose for any patient.

It is possible, of course, to train oneself to "size up" the variation from the normal in the patient's weight, as well as other problems of individual tolerance, and to adjust the dose in accordance with what he should weigh rather than to what he actually does weigh, but judgment, with the less experienced, is more likely to err than accurately calculated measurement. A scale of dosage that has proved of much value in this respect over the years, was worked out on the basis of surface area.[1] (Figure 5.) Comparing it with the standard scale based on weight, the dose of Avertin is found to be practically identical on both scales for patients of normal weight for their height, but for the abnormal, the difference in dosage is significant. For instance, for a patient of 5 ft., 4 in., weighing 200 lbs., the maximum dose computed by the surface area scale

[1] Alice M. Hunt. A newer method for computing the individual dosage of Avertin. J. Am. A. Nurse Anesthetists, 3:18.

AVERTIN DOSAGE TABULATED ACCORDING TO SURFACE AREA

Patient's Surface Area in Square Meters	Dosage Table No. 1 362.5 mg. per 0.1 sq. meter		Dosage Table No. 2 326.25 mg. per 0.1 sq. meter		Dosage Table No. 3 290 mg. per 0.1 sq. meter		Dosage Table No. 4 253.75 mg. per 0.1 sq. meter		Dosage Table No. 5 217.5 mg. per 0.1 sq. meter	
	Avertin in cc.	Water in cc.	Avertin in cc.	Water in cc.	Avertin in cc.	Water in cc.	Avertin in cc.	Water in cc.	Avertin in cc.	Water in cc.
3.00	10.9	436	9.8	392	8.7	348	7.6	304	6.5	260
2.90	10.5	420	9.5	380	8.4	336	7.4	296	6.3	252
2.80	10.2	408	9.1	364	8.1	324	7.1	284	6.1	244
2.70	9.8	392	8.8	352	7.8	312	6.9	276	5.9	236
2.60	9.4	376	8.5	340	7.5	300	6.6	264	5.7	228
2.50	9.1	364	8.2	328	7.3	292	6.3	252	5.4	216
2.40	8.7	348	7.8	312	7.0	280	6.1	244	5.2	208
2.35	8.5	340	7.7	308	6.8	276	6.0	240	5.1	204
2.30	8.3	332	7.5	300	6.7	268	5.8	232	5.0	200
2.25	8.2	328	7.3	292	6.5	260	5.7	228	4.9	196
2.20	8.0	320	7.2	284	6.4	256	5.6	224	4.8	192
2.15	7.8	312	7.0	280	6.2	248	5.5	220	4.7	188
2.10	7.6	304	6.9	276	6.1	244	5.3	212	4.6	184
2.05	7.4	296	6.7	268	5.9	236	5.2	208	4.5	180
2.00	7.3	292	6.5	260	5.8	232	5.1	204	4.3	172
1.95	7.1	284	6.4	256	5.7	228	4.9	196	4.2	168
1.90	6.9	276	6.2	248	5.5	220	4.8	192	4.1	164
1.85	6.7	268	6.1	244	5.4	216	4.7	188	4.0	160
1.80	6.5	260	5.9	236	5.2	208	4.6	184	3.9	156
1.75	6.3	252	5.7	228	5.1	204	4.4	176	3.8	152
1.70	6.2	248	5.5	220	4.9	196	4.3	172	3.7	148
1.65	6.0	240	5.4	216	4.8	192	4.2	168	3.6	144
1.60	5.8	232	5.2	208	4.6	184	4.1	164	3.5	140
1.55	5.6	224	5.1	204	4.5	180	3.9	156	3.4	136
1.50	5.4	216	4.9	196	4.4	176	3.8	152	3.3	132
1.45	5.3	212	4.7	188	4.2	168	3.7	148	3.2	128
1.40	5.1	204	4.6	184	4.1	164	3.6	144	3.1	124
1.35	4.9	196	4.4	176	3.9	156	3.4	136	2.9	116
1.30	4.7	188	4.2	168	3.8	152	3.3	132	2.8	112
1.25	4.5	180	4.1	164	3.6	144	3.2	128	2.7	108
1.20	4.3	172	3.9	156	3.5	140	3.0	120	2.6	104
1.15	4.2	168	3.8	152	3.3	132	2.9	116	2.5	100
1.10	4.0	160	3.6	144	3.2	128	2.8	112	2.4	96
1.05	3.8	152	3.4	136	3.0	120	2.7	108	2.3	92
1.00	3.6	144	3.3	132	2.9	116	2.5	100	2.2	88
0.95	3.4	136	3.1	124	2.8	112	2.4	96	2.1	84
0.90	3.3	132	2.9	116	2.6	104	2.3	92	2.0	80
0.85	3.1	124	2.8	112	2.5	100	2.2	88	1.8	72
0.80	2.9	116	2.6	104	2.3	92	2.0	80	1.7	68
0.75	2.7	108	2.4	96	2.2	88	1.9	76	1.6	64
0.70	2.5	100	2.3	92	2.0	80	1.8	72	1.5	60
0.65	2.4	96	2.1	84	1.9	76	1.6	64	1.4	56
0.60	2.2	88	2.0	80	1.7	68	1.5	60	1.3	52
0.55	2.0	80	1.8	72	1.6	64	1.4	56	1.2	48
0.50	1.8	72	1.6	64	1.45	72	1.3	52	1.1	44

Figure 5. Avertin dosage scale, tabulated according to surface area.

is 7.1 cc., and by the kilogram scale, 9.1 cc., a difference of 2 cc. Very little additional effort is involved in the use of the surface-area method. The height, as well as the weight, must be ascertained and the surface area is readily calculated by means of the DuBois chart used for computing basal metabolism. (Figure 6.) It must be remembered that in the case of small children, and of adults who are pathologically underweight, the dose based on surface area may exceed the dose based on weight. A good rule to follow is to compare the dose on both scales and give the lesser quantity of recorded drug.

Detailed care is necessary in preparation of the solution for injection. The salt is precipitated when Avertin is mixed with cold water, and decomposed to a tissue irritant if the water is too warm. Forty degrees Centigrade (104 degree Fahrenheit) is set as the optimum temperature to be used. This must be determined accurately by a thermometer. A phial of 1-1000 Congo-red solution is provided with each bottle of Avertin fluid so that the prepared solution can be tested for assurance of its fit condition. A few drops of the Congo red added to a normal solution gives it a definitely pink tinge. A blue or purple color denotes the presence of hydrobromic acid, which, with the accompanying dibromacidaldehyde, may cause a troublesome colitis upon injection into the bowel. Such a solution should, therefore, be discarded.

The rate of absorption is determined by the speed of injection of the fluid and the extent of the area and the condition of the mucosa contacted by the solution. So special care must be given to adequate cleansing of the colon by bland enemata and to the injection of the anesthetic solution. Satisfactory preparation of the bowel can usually be obtained by the use of a simple laxative given in the morning of the day before operation, followed in the evening by a thorough enema of normal saline. Soap suds may leave an obstructing film on the bowel mucosa. Unless several hours are allowed to elapse between the giving of a cleansing enema and any rectal medication, the bowel is likely to be in too irritable a state for the medication to be well retained. Enema should not be deferred, therefore, until the morning of operation.

If a small dose of morphine is deemed advisable, it should be given three quarters of an hour before the Avertin in order that its effect may be noted and the dose of Avertin regulated accordingly. The Avertin solution should be freshly prepared. It is not necessary to keep it warm. It should be introduced slowly through a rubber catheter, approximately size 24 F, or a small rectal tube inserted carefully about three inches into the rectum. The glass part of a Dakin's syringe or small funnel is attached to the tube. This should be held a few inches above the buttocks with the patient lying on either side or on his back if it is impractical for him to be turned. Care should be taken to avoid the introduction of air. Five to ten minutes should be consumed in the process of injection of the anesthetic solution. In the case of infants, small children, and other irresponsible patients, a pad should be held over the anus for a few minutes after the catheter is withdrawn or the buttocks strapped together with adhesive plaster to prevent expulsion of the fluid. Usually the patient will become drowsy, or fall asleep, within five to six minutes after the injection is completed. Under ideal conditions of preparation and administration, it has been proved that concentration of the drug in the solution has diminished one third within ten minutes after the completion of the injection, and more than one half

DUBOIS BODY SURFACE CHART
(As prepared by Boothby and Sandiford of the Mayo Clinic)

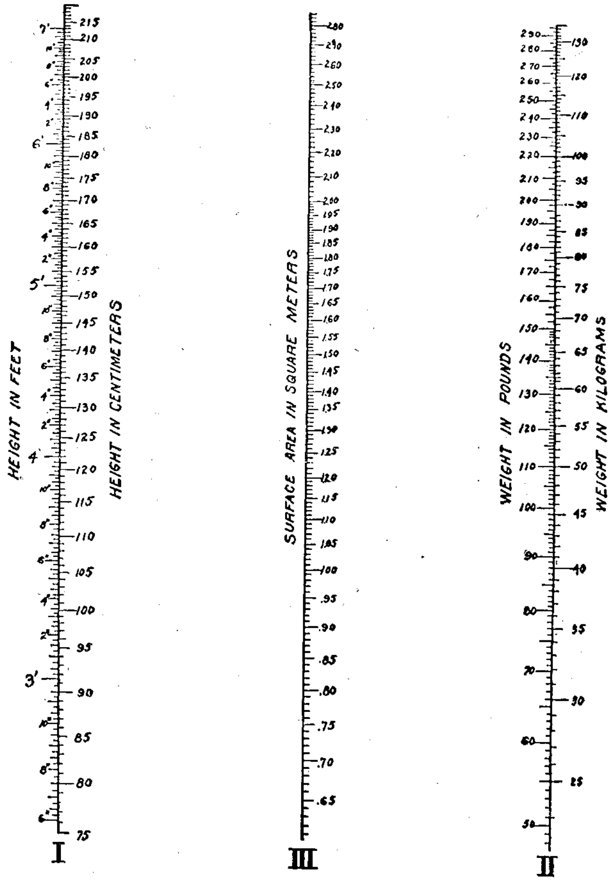

Figure 6. DuBois chart for computing surface area.

from the original strength within twenty to thirty minutes.[2] In the occasional case where the patient, seemingly, remains conscious for ten minutes or more, a state of amnesia has usually developed and the patient will have little remembrance of occurrences after the catheter was withdrawn.

The great advantage of Avertin is this period of amnesia, both pre- and postoperatively, so comfortably brought about. If the drug is given carefully and unobtrusively to the patient in bed, before removal from his room or ward, he is spared the natural emotional upset and fear of the journey to the operating room. When it is desirable, as in the case of small children and patients in such supersensitive states as that resulting from acute hyperthyroidism, the imminence of the surgical operation need not be disclosed to the patient until it is an accomplished fact. This form of basal anesthesia, in the small dosage that usually is sufficient, is invaluable as a means of preventing psychic shock for patients, especially children, needing repeated surgical operations or painful treatments at frequent intervals. It has also been proved a safe and effective treatment for control of the convulsions of tetanus and of other causes. In such cases it has sometimes been given daily over a period of a week or more with no deleterious results.[3]

Invariable success in the use of Avertin depends, as indeed with all anesthetics, upon the experience and good judgment of the anesthetist, and careful attention to detail, plus conservatism in dosage and the realization that usually the desired effect of basal anesthesia can be brought about equally well with small, as with large, doses.

[2] Walter Sebening. Recent researches and clinical advances in Avertin narcosis. Anesth. & Analg., 11:145.

[3] Robert W. Huntington, Jr. The treatment of tetanus. Yale J. Biol. & Med., 3:207.

Where it is desirable to prolong the period of sleep, as during a tedious surgical case restricted to supplementary local anesthesia, the catheter can be obtunded and left *in situ* to allow for the repetition of injection of Avertin solution. The quantity of Avertin to be used under such conditions must be determined by the reaction of the patient to the initial dose, considering also his present general condition.

Chapter 9

INTRAVENOUS ANESTHESIA

To produce general anesthesia, it is necessary that the anesthetic drug be introduced or absorbed into the blood stream. To a person familiar with the modern common practice of intravenous therapy, the method of direct injection of this drug into a vein seems simple and logical. But safe intravenous therapy is of recent date—twenty-five years or so—and the discovery of anesthetic drugs suitable for such administration is of still more recent origin. The possibility of producing sleep and anesthesia by this method was recognized by investigators much earlier; in 1872 the French scientist Oré reported the intravenous injection of chloral hydrate for surgical anesthesia; [1] but the subsequent high mortality rate ascribed to it discouraged continued use of the practice. Other drugs were tried at intervals and later discarded as unsuitable.

Early in the present century intravenous ether anesthesia had a brief vogue of limited scope. The drug was prepared as a 5-per-cent to 7-per-cent solution in sterile normal saline, or Ringer's, solution. After the

[1] James Tayloe Gwathmey, *Anesthesia*, p. 628.

needle had been inserted into the vein, the solution was started at a moderately fast flow for the induction of anesthesia and then gradually slowed to a rate of fifty to sixty drops per minute for maintenance of the surgical stage. Usually, the induction period was remarkably smooth and rapid in comparison with the inhalation ether method; the planes of anesthesia could be kept readily under control by regulation of the rate of drop, and when the flow was stopped, the patient quickly recovered consciousness. Though there were also other advantages to this method, little postoperative nausea or vomiting or irritation of the respiratory tract, it involved the giving of large quantities of saline solution, an average of 1000 cc. per hour, with the grave risk of a resulting edema of the lungs and other body tissues. Consequently, the method did not gain popularity.

As the synthesis of the barbituric acid derivatives evolved, several were given trial as intravenous anesthetics;[2] but though a few of the early discoveries proved very satisfactory experimentally, the period of unconsciousness resulting from their use intravenously was too prolonged for safety, as a routine procedure, for the human subject. The introduction of Evipan sodium (Evipal soluble) a very short-acting barbiturate, by German chemists in 1932, established intravenous anesthesia on the firm basis recognized today.

Two years later, the use of a similar short-acting drug for the purpose, pentothal sodium, a derivative of thiobarbituric acid, was described by Dr. Lundy of the Mayo Clinic. This drug has stood the test of time very well and has steadily displaced Evipal, at least in America, on the basis of affording still higher potency and lesser toxicity as an intravenous anes-

[2] R. Charles Adams, *Intravenous Anesthesia*, p. 135.

thetic. The thiobarbiturates contain a sulfur atom which is thought to hasten the destruction of the drug in the body. The sulfur gives a pale yellow color to the sodium salt. The effects of these two barbiturates are otherwise very similar, and the technique of their preparation and administration is practically the same. The drugs are commonly marketed in sealed glass ampoules containing ½ gram and 1 gram of the powder. The powdered drug dissolves readily in water and is prepared as a 2½-per-cent to 5-per-cent solution with sterile distilled water. Freshly prepared solutions are preferable, but they are sufficiently stable to be kept for several days, provided the solution is kept sterile and protected from light. The solution should not be used if it has become cloudy or otherwise changed from it original appearance.

Any normal vein of reasonably good size, which can be conveniently exposed, may be used for the venipuncture; those of the cubital fossa, dorsal area of hand and wrist, or the veins of the ankle are most commonly chosen. Of course, careful aseptic preparation of the area and application of a tourniquet proximal to the site are essential, as with any venipuncture. Choice in the size of the needle is influenced by the size of the vein and subsequent method of procedure required.

Pentothal sodium may be used for the rapid and comfortable blotting out of consciousness only as a preliminary to inhalation anesthesia. In this case, the needle is quickly discarded so one of small caliber will be adequate. The needle may be left securely inserted in the vein when the anesthesia is to be maintained or supplemented by interval injection of the solution, when a larger needle is more likely to remain patent over a long period of time. Should a supporting infusion be desirable during the surgical operation, the pentothal setup can be arranged so that the solution can be given intermittently through the needle by means of a multiple-way stopcock; the continuous drip of the infusion will prevent blockage of the needle by blood clot.

Pentothal sodium may also be given by continuous drip infusion, prepared in 0.5-per-cent to 1-per-cent concentration with normal saline. The depth of anesthesia is regulated by the rate of the drop.

The nonvolatile anesthetics, in contrast to the liquid and gaseous agents, undergo more or less chemical change in the body processes. It is generally accepted that they are detoxified, if not completely broken down, in the liver and are excreted by the kidneys and that the outstanding contraindications to the use of these drugs are signs of inefficient functioning of these organs. Evidence that the liver plays little part in the detoxification of pentothal sodium has recently been reported following animal experiments.[3] Whether or not this holds true in regard to the human body also remains to be proved. It is known definitely, by the brevity of its effects, that pentothal sodium is rapidly broken down in the tissues.

This desirable brevity of effect applies only when pentothal is used in moderate dosage, however, for the drug seems to have cumulative properties. These are evidenced in the average case by progressive depression of the respiration and circulation and delay in return of consciousness, which commonly follow large doses of the drug regardless of the length of time consumed in the operative procedure. For these reasons it is generally considered unwise to depend solely upon pentothal sodium for prolonged surgical anesthesia; but as a supplement to other drugs and meth-

[3] Charles H. Scheifley. Pentothal sodium: its use in the presence of hepatic disease. Anesthesiology, 7:263.

ods used for this purpose it is of great value. For instance, the hazard of explosion can be entirely eliminated, while excellent anesthesia is maintained, by the skilled combination of pentothal and nitrous oxide–oxygen.

For brief surgical procedures, intravenous pentothal sodium anesthesia is very satisfactory for consciousness is lost within one minute, rarely is there a stage of excitement, and muscular relaxation is sufficiently good for minor surgery or reduction of fracture. The recovery period is brief and rarely accompanied by nausea or vomiting.

Depression of respiration is the chief complicating factor of pentothal sodium anesthesia and this should be counteracted by a continuous flow of oxygen. Intrapharyngeal insufflation, by means of a nasal catheter, is a convenient way in which to administer the oxygen if a supplementary gas-oxygen machine is not being used.

The technique for intravenous anesthesia calls for careful attention to detail in preparation of the solution and skill at venipuncture for infusion. The alkaline solution is irritant to the soft tissues, and it is essential that the needle be properly placed in the vein before any of the fluid is injected. In the case of accidental injection of a portion of the solution into the tissues, gentle massage of the area and application of warm compresses aid in the absorption of the fluid and so decrease the discomfort. Should the discomfort be severe, local injection in the area of a 1-per-cent Novocain solution will give quick relief.

Warning should be given of the danger and possibility of accidental arterial puncture. Injection of the solution into an artery causes a sharp burning sensation distal to the point of entry, and complaint of this sensation by the patient calls for immediate withdrawal of the needle. Serious local interference of the circulation, even to the point of causing gangrene, has resulted from such accidental injection.[4]

The simplicity and ease of induction of intravenous pentothal sodium anesthesia should not mislead one into the belief that it can be safely undertaken by the inexperienced anesthetist, for the drug is very powerful, and there is wide variation in individual tolerance for it.

[4] R. R. Macintosh and P. S. A. Heyworth. Pentothal—arterial injection of, a warning. Lancet, 1943, pt. 2, p. 571.

Chapter 10

LOCAL ANESTHESIA

COCAINE and several synthetic salts that, for the most part, are derivatives of benzoic acid are the drugs most commonly used for local anesthesia. The least toxic and most popular of the synthetic drugs is Novocain (procaine hydrochloride). In order to induce anesthesia in a given area, a weak solution of an anesthetic drug is applied topically to mucous membrane, or injected hypodermically. The intact skin cannot be anesthetized by surface application of anesthetics.[1]

The high toxicity of the drug prohibits the hypodermic injection of cocaine, but mucous membrane is readily penetrated by the solution. The field of usefulness for cocaine as a local anesthetic is, therefore, limited to superficial areas of the eye, ear-nose-throat, and the urethra. Even this limited use of cocaine is being challenged by some of the synthetic drugs, notably Pontocaine and Butyn, which present advantages of lessened toxicity and freedom from the danger of habituation inherent in the use of cocaine.

Many surgical procedures can be performed relatively painlessly under local anesthesia. Excellent re-

[1] Henry K. Beecher, *The Physiology of Anesthesia*, p. 50.

sults depend largely upon allowing sufficient time for adequate infiltration of the drug before surgery is attempted and upon subsequent gentle handling of the tissues.

For anesthesia of mucous surfaces, the surgical area may be sprayed with the anesthetic solution, swabbed with cotton soaked in the solution, or narrow passages such as the nostrils may be packed for a short period with gauze wicking that has been saturated with the solution. For anesthesia of the cornea the solution is applied in drops to the eyeball. The anesthetic concentration of the solution should be as low as is compatible with satisfactory anesthetic results. This may range between 1 per cent and 10 per cent according to the drug used and other conditions that influence anesthetic practices in general. (Novocain is not satisfactory as an anesthetic for topical application.)

Novocain for subcutaneous injection is most commonly used in a 0.5-per-cent solution. The drug causes vasodilatation in the area of injection and a small quantity of adrenalin, 1-25,000 to 1-100,000, is usually combined with the anesthetic solution in order to counteract this effect and delay absorption of the anesthetic into the blood stream. Slowing the absorption of the drug prolongs the localized anesthesia and reduces the risk of toxicity since local anesthetics are quickly destroyed in the liver.[2] Overdosage is brought about largely by too rapid injection of the solution.

Careful, skilled injection will cause little discomfort after the first superficial wheal is made by the entering fluid, for each successive stab of the needle is made within the anesthetized area as that area is extended. When the field of operation is relatively deep, for instance, through the abdominal wall, a small-caliber

[2] John Adriani, *The Pharmacology of Anesthetic Drugs*, p. 48.

short needle is used for superficial injection, and this is replaced by a longer needle as the infiltration spreads and deepens.

The necessary apparatus for the injection of local anesthetics consists of hypodermic needles and syringes and a vial or flask of the anesthetic solution. Aseptic surgical technique is essential, of course, and the simplicity of the whole procedure makes it possible, and usually more convenient, for the anesthesia to be conducted by a member of the surgical team. The anesthesia can then be readily extended or prolonged, whenever indicated, by repeated injection of the solution; this will be found necessary during extensive operations as the average duration of Novocain anesthesia is limited to about one hour.

The danger of too rapid absorption of the drug is present when the injection of the drug is made into inflamed tissues or highly vascular areas. Apart from this danger, and acute discomfort caused by injection of the solution into acutely infected tissues, local anesthesia under such conditions is rarely efficient. This is explained on the theory that the abnormal acidity of the tissues, resulting from the bacterial activity, prevents hydrolization of the anesthetic drug.[3]

Precaution is necessary to avoid accidental intravenous injection of the anesthetic solution. The lethal dose of Novocain by intravenous injection is reported to be one tenth that of the subcutaneous lethal dose. Idiosyncrasy to Novocain is occasionally met and, of course, is a contraindication to further use of the drug.

Local anesthetics are stimulating to the central nervous system and symptoms of overdosage are signs of excitement and restlessness, which in severe conditions may progress into convulsions and coma.

[3] *Ibid.*

Intravenous injection of one of the short-acting barbiturates is accepted as the best antidote when symptoms portray severe overdosage. It is also accepted that the threshold of tolerance for local anesthetics may be raised considerably by sedative premedication of the patient with a barbiturate, and consequently such medication is especially indicated with local anesthesia.

Although the services of an anesthetist may not be necessary, constant watch must be kept of the patient's general condition and special care taken to insure his comfort. Unless the patient has been heavily premedicated and is somnolent, lying awake completely still for a prolonged time can become very tiring, especially under the condition of nervous tension evoked by anticipation of a surgical operation. An understanding nurse can contribute much to the success of local anesthesia by applying such little trifles of nursing care as ice compresses to the forehead, mopping perspiration from the face, giving the patient chips of ice to suck occasionally, and in various other ways distracting his attention from the irksomeness of the situation.

Preparation for operation under local anesthesia should include adequate padding of the operating table, and after the patient is placed in the position required by the surgeon, careful arrangement of pads and pillows for the avoidance of strain to muscles. The patient's hands should be comfortably placed and necessary restraining straps made inconspicuous and not fastened too tightly. Coverings for the patient should be limited as much as possible to the minimum for comfortable warmth, since the sterile coverings will be superimposed. The patient's eyes should be shielded from glaring light.

Muscular reflex to pain stimuli in the surgical field during manipulation of highly sensitive tissues, under general anesthesia, can be much diminished by resort to localized anesthesia. This supplementary local anesthesia will be found to increase the effectiveness of the so-called weak general anesthetics and to decrease the necessity for the maintenance of a profound depth of anesthesia when a general anesthetic drug of high potency is being used. This combined anesthesia is of great value, oftentimes, for the closure of the peritoneum in the robust type of individual who is showing high resistance to anesthetic drugs.

Local anesthesia for the incision of a small, superficial abscess can be effected by the use of a fine spray of ethyl chloride. The ampoule containing the drug is held about ten inches above the area to be anesthetized and the ethyl chloride is released for the spray to strike the area. The rapid evaporation of the drug in this way causes definite freezing with blanching and hardening of the tissues. The anesthesia is of brief duration and the recovery period, as in any form of frostbite, is somewhat painful.

Chapter 11

REGIONAL ANESTHESIA

THE term regional, or nerve-block, anesthesia implies depression of the whole sensory nerve system of a limited area of the body by the hypodermic injection of a local anesthetic solution at the focal points of nerve supply of this area. A higher concentration of the drug, Novocain 1 per cent to 2 per cent, but a lesser quantity of the fluid is needed, usually, than for the infiltration method of local anesthesia.

Regional anesthesia is applicable, for minor or major procedures, to practically all parts of the body and may involve very simple to very complicated technique, according to the site, size, and nerve supply of the area to be anesthetized. A single injection in the vicinity of the branch of a nerve may suffice, or precise identification of several nerves together with multiple injection may be necessary. The method can be used for surgical anesthesia and for therapeutic and diagnostic purposes.[1] Because the injection is not made directly into the surgical field, as is the case with infiltration anesthesia, acute localized infection is not

[1] C. Langdon Hewer, *Recent Advances in Anesthesia and Analgesia*, p. 164.

necessarily a contraindication to its use. Neither is the surgical field distorted by an edema of the tissues caused by infiltration of the solution, a condition that may seriously handicap extensive tendon repair or similar exploratory procedures.

Regional anesthesia may be sufficiently satisfactory for major surgery involving a wide area, and when it is used in combination with a general anesthetic, the need for a deep plane of anesthesia is greatly minimized.

The therapeutic use of regional-block anesthesia can be of great benefit in the alleviation of the intractable pain of many diseases, such as inoperable lesions of cancer and tertiary syphilis. It is sometimes helpful for the relief of *herpes zoster* (shingles) and in certain severe forms of bursitis, arthritis, and circulatory disorders. The treatment may have to be repeated a number of times, though under some circumstances a single treatment gives lasting relief. No entirely satisfactory explanation of the latter phenomenon has, so far, been found. Anesthetic solutions containing oil, which greatly delays local absorption, are sometimes employed in order to prolong the analgesic effect.

Intraneural injection of 95 per cent alcohol is often effective in controlling severe neuralgic pain for long periods. Alcohol is sometimes injected into the stump of the great sciatic nerve, during amputation of the thigh, to prevent the uncanny "pain in the foot" of the severed leg, a complaint that frequently follows such surgical operations.

There is also increasing appreciation of the value of regional anesthesia for diagnostic purposes in many branches of medicine and surgery. Novocain block of sympathetic-nerve ganglia may greatly facilitate diagnosis of essential hypertension and of peripheral arterial disease, and it may serve as a valuable guide in the treatment and prognosis of these cases.[2]

In order to make the induction of regional anesthesia as painless as possible, the site of injection should be carefully anesthetized through an initial intradermal wheal made with a very fine hypodermic needle, which may be replaced by longer and larger needles as the need arises. Aspiration for assurance that a blood vessel has not been inadvertently entered is always essential before deep injection is made, and especially so when the more highly concentrated solutions are being used. The additional danger of accidental puncture of the arachnoid or pleural membrane is present when the injections are to be made in the area of the neck, chest, and thorax, and this must, of course, be guarded against.

Adrenalin in the solution is contraindicated for local or block anesthesia of the fingers and toes because of the danger that the vasoconstrictor effect of the drug may be too prolonged. Gangrene of the tissues of a digit has occasionally resulted from such interference with circulation.

As a whole, regional-block anesthesia demands of the anesthetist much patience, practice, and skill and an intimate knowledge of anatomy. The duration of anesthesia for surgery is limited and, on account of varying conditions, is usually unpredictable, and some supplementary anesthesia should be available.

Similar consideration for the patient's general comfort should, of course, be given, as has been outlined under the previous heading, local anesthetics. In the postoperative care of the patient, warning should be given of the danger of burning an anesthetized area by treatments with heat in any form, applied at too high a temperature.

[2] Alton Ochsner. Anesthesia of the sympathetic system: Editorial. Anesthesiology, 4:301.

Chapter 12

SPINAL ANESTHESIA

SUBARACHNOID spinal anesthesia has passed through several phases of popularity since the inception of the method early in the twentieth century.

A small quantity of relatively innocuous local anesthetic, when injected into the spinal subarachnoid space, produces a profound degree of anesthesia in a wide area of the body without interference with consciousness. Compared to inhalation anesthesia, therefore, spinal anesthesia would seem to be the wiser choice for the poor-risk patient, whenever the method is applicable in relation to the site of the proposed surgical operation. Taking this supposition for granted and failure to appreciate the potential dangers and limitations of spinal anesthesia, together with the false sense of security imparted by the simplicity and ease of the induction period, led to the indiscriminate use of spinal anesthesia. The inevitable accidents resulting from ill-considered use of the method discredited spinal anesthesia repeatedly, but, when used with discretion, the method has been of great value. The chief advantage of spinal anesthesia is found in the excellent muscular relaxation it affords the surgeon.

The special dangers of spinal anesthesia are those of serious depression of the respiration and circulation, conditions especially incompatible with poor-risk patients. How the depression is effected is still a matter of controversy, but it is evident that the degree of depression is influenced by the quantity and concentration of the drug, the rate of injection and the level of anesthesia attained—the height to which the drug penetrates into the spinal canal. The level of anesthesia is the dominant factor, and when this goes above the costal margin there may be grave danger of failure of respiration, due to paralysis of the intercostal and phrenic nerves.

The anesthetic is brought into contact with the nerve endings in the spinal canal by diffusion of the solution in the spinal fluid. Fortunately, this diffusion is relatively slow and, if careful consideration is given to the technique of injection, the level of anesthesia can be approximated and stabilized fairly well.

The principal factors affecting diffusion of the solution are the difference in specific gravity of the solution and the spinal fluid and the volume of the solution and the speed or force with which it is injected. Unless the anesthetic solution is isobaric, *i.e.*, of the same specific gravity as the spinal fluid, the position of the patient is also of much importance, for a heavier or lighter solution will sink or rise in the spinal fluid in conformance to the laws of gravity. For instance, the level of anesthesia will be raised, when a hyperbaric solution has been given, if the patient is placed in the Trendelenburg position before the drug has become stabilized in the spinal canal. A similar effect will result when a hypobaric solution has been given, if the patient is placed in a sitting position before the drug is stabilized.

The specific gravity of spinal fluid is approximately

1.005. The drugs most commonly used in America for spinal anesthesia are Pontocaine in 1-per-cent solution, which is approximately isobaric, and Novocain in 10-per-cent solution, or in crystal form, which is definitely hyperbaric. Since Pontocaine anesthesia lasts about twice as long as that of Novocain but is isobaric, a proportion of Novocain crystals, or of glucose solution, is frequently mixed with Pontocaine during preparation of the solution in order to make it hyperbaric.

Some of the highly potent local anesthetics in aqueous solution are hypobaric, as is also the proprietary agent, Spinocaine, which is composed largely of Novocain made hypobaric by the addition of alcohol. Despite careful consideration in one's choice of drugs, however, there is no fixed law regulating diffusion of a solution in the spinal fluid, and the rate may be affected considerably by changes in the patient's respiration, spinal blood circulation, and movements of his body.[1]

The original method of inducing spinal anesthesia by the injection of a calculated single dose is always complicated by uncertainties with regard to the reaction of the individual patient to the drug and the duration of a satisfactory condition of anesthesia once it has been established. The latter aspect may give the surgeon an unfortunate sense of being hurried. A means for circumventing these uncertainties was presented in 1940 by Dr. William T. Lemmon,[2] when he published his method of continuous, or fractional, spinal anesthesia. With this method, the needle remains in the position of a subarachnoid spinal tap throughout the operation, and to it is attached a

[1] Henry K. Beecher, *The Physiology of Anesthesia*, p. 64.

[2] William T. Lemmon. A method for continuous spinal anesthesia, a preliminary report. Ann. Surg., 111:141.

length of fine rubber tubing connected with a stopcock and a 10-cc. hypodermic syringe. In this way it is possible to test the patient's tolerance for the drug with an initial small dose and prolong the anesthesia, as necessary, by repeated small doses. The method calls for substituting a flexible needle (made of malleable material, in order to lessen the danger of its breaking) for the usual rigid spinal needle and the use of specially constructed rubber tubing. A divided mattress, or other precaution, should be used to prevent pressure on the needle. A recent refinement in technique was described by Dr. E. B. Tuohy of the Mayo Clinic in 1944. It involves the substitution of a specially constructed woven catheter for the permanent needle. The catheter is introduced a short distance into the spinal canal through a larger, rigid spinal needle, which is then withdrawn. The catheter can be secured to the back with adhesive tape; it will not readily slip out, and the precautions against pressure are unnecessary.

The catheter technique has opened up possibilities of still greater control of spinal anesthesia in the form of "segmental anesthesia." [3] The term is used to indicate limitation of the area of anesthesia to the surgical field. This is done by advancing the catheter, within the spinal canal, to the position of the roots of the nerves that control that field, so that the anesthetic solution can be sprayed directly onto these nerves. By thus avoiding dilution of the anesthetic solution with the spinal fluid in the canal and applying it only where it is needed, the claim is made that excellent results can be attained with very weak solutions of Pontocaine or Novocain, and that there is

[3] Meyer Saklad, Clement S. Dwyer, Sanford Kronenberg, Edmund Neves, and Morris Sorkin. Intra-spinal segmental anesthesia, a preliminary report. Anesthesiology, 8:270.

required but a fraction of the total dose of the drug necessitated by other methods of spinal anesthesia.

Advantages of satisfactory segmental anesthesia, for prolonged major surgery, are obvious when it is realized that the degree of toxicity of a local anesthetic to the tissues of the body is in direct proportion, largely, to the degree of concentration of the injected drug, and that trifling chemical disturbances in the spinal fluid are caused by the very weak anesthetic solution.

One of the theories advanced in explanation of the marked fall of blood pressure, which so commonly accompanies spinal anesthesia, is interference to the venous return circulation due to the motor paralysis of the lower extremities. This paralysis can be avoided with segmental spinal anesthesia, and the circulation in general may be benefited thereby.

Spinal needles are from two and a half to three and a half inches in length with a gauge range of from 16 to 22 (the finer needles cause less trauma to tissues but the larger ones are necessary for the passage of the catheters). The bevel should be short, 45 degrees, in order to avoid the risk of leakage of spinal fluid, or of anesthetic solution, into the surrounding tissues from the point of the needle. The discomforts that follow spinal anesthesia, chiefly headache, can be caused by loss of fluid from the spinal canal.

The various methods of inducing spinal anesthesia involve minor differences of technique that must be followed but need not be described in detail. Suffice it to say that spinal anesthesia is usually induced with the patient lying on one side, knees flexed on the abdomen, and head and shoulders drawn forward, in order to bow the back and separate the spinal processes. Sterile precautions in the preparation of field and instruments are necessary, of course, as for any form of spinal tap. If the site of puncture is first carefully infiltrated with 0.5-per-cent Novocain solution, the procedure is practically painless. Frequently spinal fluid is used for dissolving the Novocain crystals and to make up the required volume of anesthetic solution. When a satisfactory spinal tap is confirmed, in such instances, by a continuous drip of clear fluid from the needle, a 10-cc. hypodermic syringe is attached and the necessary quantity of fluid withdrawn.

Immediately following injection of the anesthetic solution, the patient is carefully turned on his back and the position of the table is adjusted according to the specific gravity of the solution that has been given. Hyperbaric solutions are the more commonly used, and in these cases the level of anesthesia may be raised by lowering the table about 8 degrees Trendelenburg for a minute or two. The patient's neck and head must, meanwhile, be well raised in order to avoid the danger of diffusion of the anesthetic to the respiratory center in the fourth ventricle. The level of anesthesia is tested by pinching the skin lightly with tissue forceps. When the desired level is attained, the table is raised to the horizontal position and should remain so until the anesthetic drug has become "fixed." At least fifteen minutes should be allowed for this before the Trendelenburg position is used again.

Adequate sedative premedication is indicated with spinal anesthesia, and commonly ephedrine is given shortly before the spinal injection is made in order to counteract the anticipated fall of blood pressure.

The condition of the patient, in general, must be carefully watched throughout the operation by an anesthetist who is prepared to give supportive treatment including oxygen or supplementary anesthesia if indicated. Oxygen is helpful in controlling nausea that may result from a marked fall of blood pressure or as a reflex to manipulation in the upper abdomen.

Chapter 13

OBSTETRICAL ANESTHESIA

THE technique for the control of pain for the obstetric patient differs somewhat from that required for general surgery, and it is in this field of practice, especially, that the nurse may be called upon to assume the role of anesthetist. For these reasons it seems advisable that the subject should be treated individually.

During the first stage of labor, which often continues for several hours, the pain may best be relieved by the judicious use of hypnotic and analgesic drugs. Scopolamine and the barbiturates, though having little analgesic effects, offer the great boon of amnesia and the intermittent pains are quickly forgotten. Not infrequently, however, patients who have been given such drugs become disoriented and difficult to control during the bouts of pain, and this many present serious difficulties as the pains increase in frequency. The addition of an opiate to the medication will lessen the disturbance, but most authorities agree that the spontaneous respiration of the baby, at birth, may be critically delayed when the mother has had morphine unless about four hours have elapsed since the dose was given.

Rectal injection of ether and oil, advocated by Dr. Gwathmey, provides good analgesia during this stage, lasting for several hours. The injection is made while the patient lies on her left side with the buttocks slightly raised. A number 24-F rubber catheter, to which a small funnel is attached, is well lubricated, filled with oil, and inserted gently into the rectum for three to four inches. The ether-oil mixture, $2\frac{1}{2}$ oz. ether, $1\frac{1}{2}$ oz. oil, is then allowed to flow in slowly by gravity, at least ten minutes being allowed for this. Care must be taken, meanwhile, to prevent the introduction of air through the catheter. During a pain the solution may be forced back into the funnel temporarily, and provision should be made for this by not keeping the funnel too nearly filled. When the injection is completed, the catheter is gently withdrawn, and a pad and pressure with the hand applied over the anus for several minutes until all desire to expel the enema has subsided. The injection may be repeated at three- to four-hour intervals if the labor is prolonged. Should the pains become too frequent and severe, inhalation of a supplementary anesthetic may be indicated in order to afford rest to the mother and to prevent circulatory interference with the fetus from incomplete relaxation of the uterine walls between contractions. Intermittent inhalation of an anesthetic at this time will often slow down uterine contractions.

The characteristic pain of the first stage of labor is located principally in the lower part of the back, radiating around to the abdomen. The patient should be discouraged from "bearing down" at this stage for the cervix is not fully dilated, and the useless effort would needlessly tire her. On the other hand, with the onset of the second stage of labor, when the cervix is fully dilated, the expulsive nature of the pains stimulate an urge on the patient's part to "bear down," and she should be encouraged to do so as persistently as possible for the full duration of each pain. The anesthetist can greatly help the patient to a satisfactory termination of the labor by teaching her in this way to get the full value of each pain. The inhaled anesthetic, at this time, should be limited to the quantity necessary to induce analgesia only, the patient remaining sufficiently conscious to be able to obey the simple, definite directions of the anesthetist.

Though a patient may at first be reluctant to inhale an anesthetic, once she has been persuaded to do so she is usually so impressed with the relief it affords her that she begs for its continuance. If the need arises for an episiotomy or for the application of "low forceps," the analgesia is allowed to develop into anesthesia. Full surgical anesthesia is necessary for a "high forceps" delivery, for the performance of version, and for extensive perineal repair. Inhaled ether is too slow in its effects to be of much value for obstetrical intermittent analgesia, but nitrous oxide–oxygen, 80/20 per cent, is very satisfactory since this anesthetic gives both quick relief and recovery, and a state of anesthesia can be readily superimposed whenever indicated. By the addition of a little ether vapor, or cyclopropane, after consciousness is lost, the plane of anesthesia can be deepened at will.

When the analgesia technique is to be started, it should first be explained to the patient that she is not going to be "put to sleep" and that she will only be given enough anesthetic to dull the pain and make it bearable, so that she can work with it. She should be told to warn the anesthetist as soon as the pain begins, that the face mask will then be applied, and that she should take a deep breath of the anesthetic and "hold it." It must be explained that if she will do so the anesthetic will seep into her lungs and give her much more relief from the pain than if she lets it escape by opening her mouth to cry out. Despite this preliminary explanation of the procedure which is to be followed, usually the anesthetist has to repeat the directions many times, in simplified form: "Take a deep breath, hold it!" When the cervix is fully dilated, these directions are amplified to: "Take a deep breath, hold it, bear down!"

If waste of gas is prevented by a reasonably tight adjustment of the mask to the face, the exhaling valve remaining closed meanwhile, the gas can be effectively rebreathed and, often, one filling of the bag will be sufficient for the control of each pain. When the pain subsides the face mask is removed, and the bag is emptied and refilled with nitrous oxide and oxygen in readiness for the next pain.

Nausea can sometimes be relieved by an increase in the proportion of oxygen, but it is well to turn the patient's head to one side, and if vomiting occurs, the mask must immediately be removed from the face and further precautions taken against aspiration of vomitus.

Prerequisite for the safe, simple, and economical use of nitrous oxide–oxygen is that the person who is to administer it be familiar with the gas-oxygen apparatus, and, at a moment's notice, be able to recognize the need for, and supply, additional oxygen.

Much publicity has been given in recent years to the use of caudal anesthesia for control of the pain of childbirth, and under ideal conditions the method is spectacularly effective.[1] But it seems unlikely that

[1] R. Charles Adams, John S. Lundy, and Thomas H. Seldon. Continuous caudal anesthesia of analgesia: a consideration of the technic, various uses and some possible dangers. J.A.M.A., 122:152.

caudal anesthesia for obstetrics will become routine, for skill in its application calls for considerable practice and highly specialized technique. It is contraindicated with the highly emotional individual and in conditions that rather commonly complicate term pregnancy, *i.e.*, low blood pressure, placenta previa, and infection near the site of injection.

In order to provide complete relief of pain from the uterine contractions, the level of anesthesia of the abdominal wall must extend to about midway between the symphysis and the umbilicus, and it must be possible to supplement the anesthesia readily as the effect wears off. These needs can be accomplished by the application of a local-anesthetic solution to the nerves emerging into the sacral canal below the dural sac by means of an implanted malleable spinal needle or catheter setup, similar to that described for continuous spinal anesthesia. Entrance to the sacral canal is made through the sacral hiatus, which may be difficult to identify, especially under the physical handicaps presented by full-term pregnancy and in the obese patient. Also, abnormalities of the sacral vertebra are not uncommon.[2] On insertion of the needle, initial aspiration is essential to avoid the grave risk of injection of the anesthetic solution into the blood stream, or within the dural sac, as the area is very vascular and, in some individuals, the dural sac extends abnormally low. If blood or spinal fluid is aspirated, it is generally considered advisable to abandon the procedure altogether. Meticulous aseptic precautions to avoid contamination of the apparatus and solution by vaginal and rectal excretions must be taken, and also special care against breakage or acci-

[2] Robert A. Hingson and Waldo B. Edwards. Comprehensive review of continuous caudal analgesia for anesthetists. Anesthesiology, 4:181.

dental withdrawal of the needle or catheter must be exercised.

Progress of the labor is not readily evidenced when all pain is abolished, and the patient needs the close attendance of the obstetrician throughout the period of anesthesia. It is generally conceded by proponents of this form of anesthesia that a greater proportion of the patients require forceps delivery when the method is used. The main reason given for this is that, although the first stage of labor may be shortened, often the second stage is prolonged because the patient has no urge to bear down and expel the fetus when the perineum is completely anesthetized. However, the profound muscular relaxation afforded by caudal anesthesia greatly increases the ease of application of the forceps and completion of the third stage of labor. Provided the mother does not experience a marked fall of blood pressure, the baby is little affected by the anesthetic and usually cries spontaneously on delivery.

The anesthetic drugs most commonly used for continuous caudal anesthesia in obstetric practice are metycaine 1.5 per cent or procaine 1.5 per cent in physiological saline solution. Metycaine gives the more prolonged effect. The quantity of either drug required depends, of course, upon the point during labor at which the anesthesia is started and upon the duration of the labor.

The term "saddle-block anesthesia" is used to describe a low spinal anesthesia induced by the careful subarachnoid injection of a single dose of a hyperbaric solution of a local anesthetic. This method is more predictable of success, and easier of accomplishment, than caudal anesthesia when complete pelvic anesthesia is indicated for a relatively short time.[3]

[3] M. L. Berlowe and F. L. Herrick. Painless labor with heavy nupercaine. Conn. St. Med. J. 12:417.

A study of the effectiveness of "mind over matter" in regard to the pain of childbirth, now being conducted at the New Haven Hospital clinic, should be of special interest to nurses. It was inaugurated to study the principle that, being a natural function of a woman's body, childbirth should be devoid of pain because "there is no physiological function in the body which gives rise to pain in the normal course of health." This theory has been emphasized particularly by Dr. Grantly Dick Read of London. He also states that the parturient woman is deprived of experiencing "an ecstasy unsurpassed by any previous experience in her life" when her mental faculties are beclouded or obliterated at such a time by hypnotic or anesthetic drugs.

It has long been a matter of historical interest that to primitive woman children were born with surprisingly little discomfort. For instance, in the heyday of the American Indian when the tribe was on the march, it was commonplace for a pregnant squaw, at term, to stop alone by the wayside for her babe to be born, then, as a matter of course, to catch up with the tribe at their next resting place.

A tradition of fear of pain and of the unknown, built up throughout the ages of civilization, resulting in abnormal tension, is blamed by Dr. Read for most of the pain during labor. From the scientific standpoint he explains that there are two types of uterine muscles involved in labor, those of the fundus and of the cervix, controlled by different plexuses of nerves, which normally compensate each other. But if at the beginning of labor the normal contractions of the fundus are interpreted as pain, fear of this pain stimulates the sympathetic nervous system, which controls the muscles of the cervix, causing these muscles to contract while the fundus is trying to expel the fetus.

Opposition between these two sets of muscles gives rise to pain.

Dr. Read's book, *Childbirth Without Fear*,[4] describes how this fear, and consequent pain, can be prevented by cultivation of the patient's understanding of the physiology of pregnancy and labor and of the subsequent symptoms that she will probably experience. In the large majority of normal cases, he states, this will lead to the enthusiastic co-operation and satisfaction of the patient. The study in progress under the auspices of the Department of Obstetrics and Gynecology of the Yale University School of Medicine, at present totaling approximately one hundred cases, amply justifies this prediction.

Success depends largely upon the temperament and intelligence of the patient and the interested and understanding effort of the obstetrician and all those attendant upon her. An essential contributing factor is that in view of the patient's general physical condition she must be expected to have a normal labor.

The process of labor is interpreted to the patient as it progresses, emphasis being given to the importance of general muscular relaxation. She is assured, meanwhile, that she will not be required to suffer pain and that an anesthetic is at hand for her to resort to at will. Experience has shown that rarely does a patient feel the need of availing herself of this medication.

[4] Grantly Dick Read, *Childbirth Without Fear, The Principles and Practice of Natural Childbirth.*

Chapter 14

ENDOTRACHEAL ANESTHESIA

A PERFECT airway can practically always be assured, during general anesthesia, by the use of an endotracheal (intratracheal) tube. There are several varieties of this apparatus in sizes suitable for all ages of patients. The tube can be inserted while the patient is conscious if adequate topical local anesthesia has been effected beforehand, but, usually, intubation is not attempted until a stage of general surgical anesthesia has been reached. The plane of anesthesia necessary for intubation depends largely upon the experience and skill of the anesthetist in this particular technique. "Practice makes perfect," and it is worth while for the anesthetist to acquire this skill, but the beginner must avoid haste and should not attempt intubation until the patient is in a relatively deep plane of ether anesthesia. There are two methods of introduction of the tube: (1) "Blind" intubation denotes passage of a curved, moderately soft rubber tube through one of the nasal orifices, past the glottis, and into the trachea; proper curvature of the tube and position of the head and neck tend to prevent the point of the tube from entering the easily accessible esophagus. (2) "Direct vision" intubation requires the use of a laryngoscope (Figure 7) to expose the glottis, the tube being passed during inspiration. Twice the distance between the opening of the ear and the ala of the nose provides a rough estimate for the length of the tube required. The distal end of the tube must not quite reach the bifurcation of the trachea. The mouth of the patient should be kept moderately open by means of a rubber or firm gauze-roll prop inserted between the teeth, in order to protect the proximal end of the tube from occlusion by biting. Adaptors are available for connecting the tube to the gas machine.

It is also quite possible to continue the anesthesia by means of a face mask, either open or closed, the endotracheal catheter acting merely as an airway and a ready means for suctioning drainage from the lungs or bronchi.

If a closed circuit for rebreathing is desired, a leak-proof adjustment can be made by one of two methods: a balloon cuff can be attached to the catheter and inflated to a size sufficient to fill in the lumen of the trachea after the catheter has been introduced, or the pharynx around the catheter can be lightly packed with moistened gauze. Mineral oil is the best moistening medium. Either of these methods are valuable also in preventing aspiration of emesis or of debris from surgery of the nose or mouth.

An endotracheal tube *in situ* is almost essential for the safety of the patient in a certain few surgical procedures. These include those that involve the danger of aspiration of septic material, those in which there is need for repeated suctioning of the deep air passages during operation, those with obstructive lesions of the respiratory system or its immediate neighborhood (the catheter can be inserted via a tracheotomy wound, if necessary), and those where "controlled res-

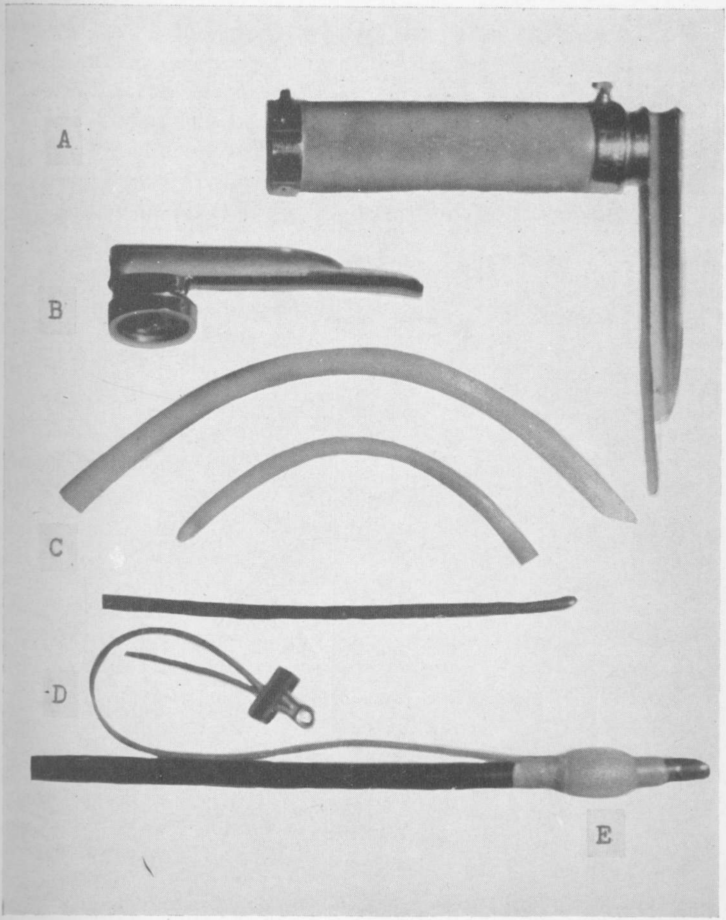

Figure 7. Endotracheal apparatus. Available in various sizes and types and from various firms. The instruments illustrated are from the Foregger Co., New York. A) laryngoscope; B) laryngoscope blade, child's size; C) endotracheal tubes, for nasal or oral route; D) endotracheal tubes, oral; E) balloon cuff, inflated.

piration" is indicated to offset the profound muscular relaxation that may be required by the surgeon. However, in the large majority of cases, a satisfactorily clear airway can be maintained by more simple means and the routine use of the endotracheal tube for the general run of patients is condemned by many practitioners as potentially harmful and impracticable.

Chapter 15

CURARE

THE acceptance of curare as a therapeutic agent by the medical profession is another instance of the harnessing of a virulent poison for the service of mankind. Curare is the drug that, for centuries, was used by the South American Indians to poison the tips of their arrows for hunting and warfare. Penetration of the arrow, even in a nonvital part of the body, dramatically felled the victim in a state of complete helplessness. The poison was obtained from a brew of leaves, bark, and roots of various plants indigenous to northern and western South America.

Samples of the crude drug, in the form of paste, which were obtained occasionally by foreign explorers, were investigated by European physiologists of the nineteenth and early twentieth centuries, and some interesting discoveries were made regarding it.[1] Among these discoveries were the facts that the drug, in controlled dosage, causes temporary paralysis of the skeletal muscles and that its primary poisonous effect is paralysis of the muscles of respiration. Research

[1] Richard C. Gill, Curare: Misconceptions regarding the discovery and development of the present form of the drug. Anesthesiology, 7:14.

with the drug was greatly restricted by scarcity of the product and lack of knowledge of its origin.

The modern use of curare in clinical medicine was made possible by the American explorer and botanist, Richard C. Gill,[2] who, having been impressed by the therapeutic possibilities of the drug by a previous personal experience, organized an expedition into South America in order to learn the botanical source of curare and the methods by which the drug was extracted and compounded. He spent many months in the jungle and gained the confidence of the Indians sufficiently to be able to fulfill the purpose of the expedition.

The following year, laboratory research with the crude drug resulted in the production of a purified and stable preparation suitable for therapeutic use, which was put on the market in 1939 by E. R. Squibb and Sons under the name Intocostrin, the active principle of which is d-tubocurarine chloride.

The selective action of curare on the skeletal muscles of the body having been proved in the laboratory, it was to be expected that the early clinical use of the purified drug would be in the treatment of convulsions and various spastic conditions. The results of such treatments suggested possibilities that the relaxant effects of Intocostrin might be of value in general surgical anesthesia, and this impression was first confirmed by Dr. Harold Griffith of Montreal. A report of the first series of cases in which he used Intocostrin in conjunction with general anesthesia, was published in 1942.[3] This spurred the interest of anesthetists and resulted in the current prominence attained by derivatives of curare in the practice of anesthesia.

[2] Stuart C. Cullen. Curare: its past and present. Anesthesiology, 8:479.

[3] Harold R. Griffith and G. Enid Johnson. The use of curare in general anesthesia. Anesthesiology, 3:418.

It is generally accepted, for it has long been evidenced by the reaction of the patients, that the toxic effect of a general anesthetic increases as the plane, or depth, of anesthesia increases. As a rule, a patient shows signs of much more prostration following a relatively short anesthesia of high concentration than after a prolonged anesthesia carried in a light plane. But a light plane of anesthesia may be inefficient in controlling the muscular reflex of movement or spasm stimulated by pain at the surgical field. This, in turn, may prove a serious handicap to the surgeon and may have disastrous results for the patient. Realizing these disadvantages and limitations, which complicate the maintenance of an ideal general anesthesia, surgeons and anesthetists have sought to control muscular reaction by other means than by deepening the plane of anesthesia. The blocking of sensory-nerve impulses from the surgical field, with a local anesthetic, proved the most effective means of doing this. The peripheral nervous system is not readily depressed by the general anesthetic drugs, which are primarily central depressants. All forms of local anesthesia, however, have certain drawbacks and are, in varying degree, time consuming. Once proof had been given that curare could be safely used with general anesthesia, the ease and simplicity of its administration and the predictability of its effective results, in comparison to those of local anesthesia, assured its adoption by professional anesthetists.

Curare is not an anesthetic. The effect of the drug on the skeletal muscles, marked flaccidity, is ascribed to its ability to interrupt nerve impulses at the neuromuscular junction. In therapeutic dosage, this effect is transitory and can be kept well under control. The drug seems to be remarkably free from harmful side effects.[4] A single small dose, given intravenously when the patient is in first-plane surgical anesthesia, immediately relaxes the muscles of the face, throat, neck, extremities, and abdomen in sequence. The maintenance of a perfectly clear airway is essential for the patient's safety.

The dose is regulated in accordance with the anesthetic drug that is being used and the age and weight of the patient. As in the case of all drugs, variation in individual susceptibility to curare will be found and only the smallest effective dose should be used. Large doses cause paralysis of the intercostal muscles and the diaphragm. This extreme condition is sometimes intentionally effected in order to still the respiratory movements in the surgical field; respiratory exchange is then maintained by rhythmic pressure of the breathing bag, which is kept well inflated with the anesthetic vapor and an adequate proportion of oxygen.

Thus the value of curare lies in the fact that by its carefully controlled use, muscular relaxation, adequate for the surgeon's need, can be maintained while the patient is kept in a plane of light anesthesia. On the other hand, the drug presents danger in that the characteristic signs of anesthesia are obliterated. Although in some instances unconsciousness has developed when curare has been given, without an anesthetic, in dosage sufficient to cause paralysis of the respiration,[5] it has been proved that the patient may remain keenly sensitive to pain and fear while being unable to demonstrate his distress.[6]

[4] Benjamin H. Robbins and J. S. Lundy. Curare and curare-like compounds, a review. Anesthesiology, 8:348.

[5] R. J. Whitacre and A. J. Fisher. Clinical observations on the use of curare in anesthesia. Anesthesiology, 6:124.

[6] Scott M. Smith, Hugh O. Brown, James E. P. Tomans, and Louis S. Goodman. The lack of cerebral effects of d-Tubocurarine. Anesthesiology, 8:1.

Two preparations of curare are available at the present time, Intocostrin and d-tubocurarine chloride solution. One cc. of either preparation represents twenty units of standardized curare, 3 mgm. of d-tubocurarine chloride. The solution is nonirritating to the body tissues and may be given by intravenous or intramuscular injection. The former method is considered to be the more readily controllable. The period of muscular relaxation is relatively short, for the drug quickly disappears from the blood stream. Therefore, repeated small doses may be given if indicated.

Warning has been given that ether has a "curariform action," [7] and that a much smaller dose of curare is indicated when the anesthesia is to be maintained with ether than when one of the anesthetic gases is to be used. While prostigmine is the pharmacological antidote for the peripheral action of curare, its use is not advocated when there is evidence that depression of the central nervous system has resulted from an overdose of the drug.[8]

From consideration of these characteristics of curare, it is evident that clinical use of this drug should be undertaken only by the highly skilled anesthetist and that preparation for intratracheal intubation should always be in readiness in case the need for artificial respiration should arise.

[7] Stuart C. Cullen. Clinical and laboratory observations on the use of curare during inhalation anesthesia. Anesthesiology, 5:166.

[8] Smith, Brown, Tomans, and Goodman, *loc. cit.*

Chapter 16

DANGEROUS POTENTIALITIES

ACCIDENT cases and others admitted to the hospital for emergency operations often present complicating difficulties for the anesthetist, especially that of the possibility of food being in the stomach. This condition is a very serious hazard because of the probability that the induction of general anesthesia may precipitate emesis and the unconscious patient may be choked by masses of undigested food or that particles of gastric contents may be aspirated and result in postoperative pneumonia or lung abscess. Many fatalities have been reported from such happenings.

A report that several hours have elapsed since the last meal was eaten cannot safely be taken as proof that the food has left the stomach. In the presence of pain, fear, or the emotional disturbance occasioned by the accident and/or admission to the hospital, digestion may be markedly delayed or entirely stopped. This is particularly true if morphine has been given early. Proof of this interruption of digestion has been abundantly evidenced.

Serious misunderstanding also can arise when the patient's admission to the hospital for an elective operation is delayed until the day on which the operation is to be performed. The doctor's order of "no breakfast" is commonly misconstrued as not to include milk or even toast and cereal. The child patient may have made a surreptitious "raid on the icebox" and hastily swallowed a glassful of milk which, later, during the anesthesia, may be vomited as a large, heavy, dangerously obstructing curd. The pernicious habit of bribing a child to submit to the ordeal of going to the hospital by treating him, en route, to a bar or two of chocolate or an ice cream cone is to be anticipated. Admission of such misunderstandings and indiscretions may not be readily forthcoming until after the regrettable accident has happened.

The complication of a full stomach is frequently met in obstetrics and may be sometimes unavoidable with the short labor of many multiparæ. How best to cope with this serious problem is often a baffling question for the anesthetist. Gastric lavage is not sufficiently effective in removing solid food unless the passage of the stomach tube precipitates spontaneous vomiting. An anesthetic which effects a smooth, quick induction without anoxia (oxygen want) should be chosen in an effort to prevent stimulation of the vomiting center. On the first sign of impending vomiting, however, the anesthetic mask must be removed, the mouth opened, and the head and shoulders of the patient turned well to one side; it may be necessary to slap the back sharply with the palm of the hand in order to dislodge solid matter from the esophagus, and to swab out the patient's mouth. The patient should be allowed to waken sufficiently to obey an order to cough well in an effort to clear the air passages. Suction apparatus is of little help unless the material is of liquid consistency only. The above precautions should be followed also, when indicated, during the stage of recovery from anesthesia.

Cases of acute intestinal obstruction, of advanced stage, are grave risks for general anesthesia. Peristalsis is sometimes reversed in this condition, causing a more or less continuous flow of fluid intestinal material into the stomach and up into the throat and mouth. The chances of aspiration of some of this fluid, or prevention of drowning in it, may be lessened somewhat by keeping the patient in Trendelenburg position for posture drainage. This is more effective if a stomach or intestinal tube has been inserted and left in place; the tube can pass from under one side of the face mask to drain by gravity or suction into a pan or bottle.

Another danger inherent in some forms of anesthesia nowadays is that of explosion. This danger was introduced with the modern method of inhalation anesthesia in which the anesthetic vapor, combined with oxygen, is enclosed in a rubber bag. Should the anesthetic be inflammable and be accidentally ignited, the oxygen would greatly add to the force of the explosion. If this should happen during the course of anesthesia, a fatality due to rupture of the patient's lungs would be almost inevitable because the securely fastened face mask is connected to the bag by rubber tubing.

By the open-drop method on the other hand, danger from an inflammable anesthetic that might be ignited by proximity to an open flame or sparking electric equipment is limited to that of fire, which may offer some chance of controllability. Whatever the method employed, however, the combined use of an inflammable anesthetic and an evident cause for its possible ignition is reprehensible because it is potentially very dangerous.

Unfortunately, the careful elimination of evident means of ignition may not insure safety from explosion since conditions sometimes contribute to a build-up of static electricity in and about the gas-oxygen machine, and should a "spark point" be reached (the electrostatic potential be suddenly discharged), an explosion might occur.

Static electricity is most prevalent in dry cold weather, as is commonly evident in the sparking, snapping, or clinging effect produced by friction on silk and woolen clothing and blankets. These articles are nonconductive to electricity and should not be worn in the operating room; rayon garments and nonconductive rubber-soled shoes are also sources of danger. The anesthetist must be careful to avoid all forms of friction in handling the anesthetic apparatus and the pillows and coverings about the patient's head.

Raising the humidity (water content) of the surrounding atmosphere is an effective means of lessening the danger of electrostatic ignition; it is claimed that the slight film of water, deposited on all objects when the relative humidity level is 54 per cent or more, harmlessly dissipates static charges as they form.[1] The inside of the face mask, breathing tubes, and bag should be moistened with water before they are used.

A simple and inexpensive intercoupling apparatus [2] is available also for diminishing build-up of electrostatic charges, but this protection is limited strictly to the objects intercoupled, and constant vigilance is necessary to prevent its being broken by contact with a person who happens to be highly charged.

The importance of stressing the risk of explosion is real, but the danger should not be overemphasized. With the experience of twenty-five years in a "teaching hospital" where inflammable gaseous anesthetics

[1] Donald Guthrie and K. W. Woodhouse. Safety factors in ethylene anesthesia. J.A.M.A., 114:1846.

[2] The Horton intercoupler, devised by Professor J. Warren Horton of Massachusetts Institute of Technology and obtainable from the manufacturers of gas-oxygen equipment and medical gases.

have been administered daily, under close supervision, by a great many inexperienced students, the author feels justified in endorsing the opinion that, with the observance of reasonable precautions, explosion is one of the least of the hazards of anesthesia; we have had the good fortune never to have suffered a fire or explosion.

Chapter 17

OXYGEN THERAPY

Oxygen therapy holds a place of wide significance today, and a brief review of the subject may well be included in a review of anesthesia, for it owes its successful growth largely to the understanding and development of the gaseous anesthetics. The cylinders in which oxygen is stored and the equipment provided for its delivery to the patient are practically identical with those used for all types of medical gases, and the same care is necessary in handling them. Because the anesthetist is so familiar with the use and importance of oxygen in anesthesia and with the essential equipment, it is logical that, increasingly, oxygen therapy is being included among the responsibilities of the anesthesia staff.

Normally, an ample supply of oxygen is available in the atmosphere for the needs of the body, and the level of supply is kept very constant by the functions of respiration and circulation. But if these functions are impeded in any way, or the inhaled atmosphere is too rarefied, a state of anoxia (oxygen deficiency) will prevail in the body. The symptoms of distress, the tissue damage, and the possibility of fatality resulting from anoxia parallel the severity and duration of the oxygen deficiency and the age and state of health of the individual concerned. In many cases the administration of additional oxygen, if it is given sufficiently early and in adequate quantity, will effectively offset these discomforts and dangers.

The most simple way of administering oxygen is by means of a nasal catheter. To avoid dilatation of the stomach by the oxygen, and to insure its adequate absorption into the lungs, it is essential that the tip of the catheter be properly placed within the oropharynx [1] and its movement prevented by fastening it securely to the face with adhesive tape. A means of increasing the humidity of the oxygen, to prevent discomforting drying of the mucosa of the pharynx, is provided by a water bottle through which the gas is bubbled. Agitation of a generous quantity of water is necessary for this purpose, but precaution must be taken against the possibility of overflow to the catheter. Therefore, it is important that the water be kept at the correct level, and this level should be plainly marked on the bottle.

The B.L.B. mask, especially designed for the purpose of oxygen therapy by Drs. Boothby, Lovelace, and Bulbulian also affords a simple and effective means of administration of the gas, either by mouth or nasal breathing. A single large cylinder of oxygen, supplied with a pressure-reducing gauge and humidifier, completes the necessary equipment for either of these methods.

Several models of oxygen tents are on the market but the essential features of them all are devices for the maintenance of the required proportion of oxygen, prevention of the accumulation of carbon dioxide, and

[1] E. A. Rovenstine, I. B. Taylor, and K. W. Lemmer. Oropharyngeal insufflation of oxygen: gas tensions in the bronchus. Anesth. & Analg., 15:10.

proper regulation of the temperature and humidity of the enclosed atmosphere. The tent should be large enough and have plenty of visibility in the way of clear window material so that the patient does not feel too "shut in." The mattress beneath the canopy needs to be covered securely by waterproof material in order to prevent it from absorbing a high proportion of the oxygen.

If soda-lime is used for the absorption of carbon dioxide, it should be understood that the period of its efficiency depends upon the amount of carbon dioxide that is being exhaled by the individual patient and that this is increased markedly by each additional degree of fever, by pain, fear, or activity. Consequently, the time of need for renewal of the charge of soda-lime may vary greatly, and the percentage of carbon dioxide within the tent should be ascertained at frequent and regular intervals. If ice is used for the cooling system, a sufficient quantity must be maintained and the drainage pipe kept clear to prevent accumulation of water in the chamber.

Elaborate, yet compact, apparatus is now available. It embodies automatic electric control of all the essential features of an oxygen tent, verification of which is indicated on an illuminated instrument panel. The evolution of such a machine, in this miracle age of electric control, was to be expected, and doubtless it will simplify efficient management of this form of oxygen therapy. But mechanical gadgets must not be relied upon to supplant human intelligence. A trifling mishap may put a stop to the most elaborate machinery, and the pilot dare not sleep while the robot manages the controls.

Although oxygen is not an inflammable gas, it greatly intensifies combustion. For instance, in the presence of free oxygen a barely smoldering cigarette will burst into acute flame. Consequently, warning of the danger of fire when oxygen is being used must be plainly emphasized.

Combination of helium and oxygen is used to introduce oxygen when there is partial obstruction of the airway, which cannot be overcome by mechanical means. The bronchial constriction of asthma, especially during acute spasm, is the classical example of such obstruction. The atomic weight of helium is only 4, that of nitrogen is 14. When a combination of 20 per cent oxygen and 80 per cent helium is substituted for air, which consists of 20 per cent oxygen and 80 per cent nitrogen approximately, the atmosphere breathed by the patient is only one third the weight of air and will pass through a constricted passage much more readily.

For therapeutic use, the helium cylinder should always contain at least 20 per cent oxygen, in order to avoid the risk of asphyxiation of the patient from premature emptying of the oxygen cylinder when separate cylinders are being used. Sometimes a higher proportion of oxygen is indicated and this can readily be made available by the insertion of a Y connection in the delivery tube, to which is attached a cylinder of oxygen.

Oxygen under carefully controlled positive pressure has been found very effective in the treatment of acute pulmonary edema due to cardiac ventricular failure.[2] This method of oxygen therapy requires the use of a breathing bag and close-fitting face mask or breathing tubes.

[2] Alvan R. Barach, John Martin, and Morris Eckman. Positive pressure respiration and its application to the treatment of acute pulmonary edema. Ann. Int. Med., 12:754.

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