Fundamentals of

ANESTHESIA

AN OUTLINE

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By

SUBCOMMITTEE ON ANESTHESIA OF
NATIONAL RESEARCH COUNCIL

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LIST OF ILLUSTRATIONS—Continued

Preface

A STATE OF EMERGENCY prevails in the world. In an effort to meet it, this country is undertaking a great expansion in the personnel of its armed forces. Many medical men will find themselves confronted with the task of administering anesthetics and of treating respiratory and circulatory emergencies, as well as of applying the principles of resuscitation and gaseous therapy.

The National Research Council has appointed committees to serve in an advisory capacity to the armed forces. The Subcommittee on Anesthesia has sponsored the appearance of this manual, which has a dual function. It is primarily intended to serve as a basis for the instruction of medical officers as anesthetists. Since its emphasis is on the principles governing safety in the administration of depressant drugs and the care of patients in a state of respiratory or circulatory depression, it is hoped that it may prove useful to a wider range of readers: surgeons, medical officers, wardmasters and others.

The material has been drawn from a wide range of sources. Much of it was issued in pamphlet form by the American Medical Association at their meetings in Atlantic City (1937), San Francisco (1938) and St. Louis (1939). Further material has been contributed by the members of the Subcommittee on Anesthesia, who have been assisted in this task by their associates, assistants and students. The American Medical Association has contributed by placing its publishing and printing facilities at the disposal of the Subcommittee.

The necessary brevity of such a manual perforce makes it appear dogmatic. An effort has, however, been made to dwell on principles at the expense of detail. The Subcommittee recognizes that there can be no such thing as "routine" in the treatment of individual patients, for each case is a problem in itself. It realizes that the choice of drugs is secondary to their judicious and skilled use, and that the appropriate dose can be ascertained clinically only by the effect on each particular patient.

The following pages therefore attempt to set forth: (1) the simple principles of physiology, pharmacology, chemistry and physics on which the sound practices of anesthesiology are based, (2) the technical procedures necessary to apply these principles effectively in relieving surgical pain and (3) the application of these principles to the management of patients suffering from injury, illness, operation or the effects of depressant drugs in the hospital or in the field.

Illustrations have been taken from various sources, and individual credit to the author and to the publisher has been omitted. A list of the original publishers so far as known is appended.

American Medical Association Anesthesia Pamphlets
Figures 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 19, 20, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 51, 52, 60.

W. B. Saunders Company, Philadelphia
Figures 49, 50, 54, 55, 56, 57.

American Journal of Surgery
Figures 46 (modified), 47, 48.

The Mayo Clinic
Figures 58, 59.

Current Researches in Anesthesia and Analgesia
Figures 17, 18.

Anesthesiology
Figure 2A.

F. A. Davis Company, Philadelphia
Figure 53A.

Lancet, London
Figure 67.

Royal Society of Medicine
Figure 70. (This illustration is reprinted from the *Proceedings of the Royal Society of Medicine* [**34**:479, 1941] by permission of the Honorary Editors.)

Martin, S. J., and Makel, H. P.: Organization of a Section on Resuscitation and Oxygen Therapy, Army M. Bull., to be published.
Figure 2B.

I

Records

IMPROVEMENT in clinical practice, teaching and statistical study must be based on an adequate record. The maintenance of such a record promotes more careful attention to the patient.

The record sheet contains on the obverse a detailed record of the technic of administration of the anesthetic and observations on the patient's blood pressure, pulse rate and respiratory rate; the reverse is divided between the preoperative and the postoperative condition of each system of the body.

In the course of rounds before operation, the condition of each system is evaluated from the history and the results of the physical examination and special investigations. The appropriate preoperative medication is then prescribed. During the administration of the anesthetic itself, the obverse of the chart is filled in. After operation, any postoperative complications are noted on the reverse of the chart.

Data collected on the record sheet are available for comparison with data in similar cases, for teaching purposes and for the information of the surgeon or the hospital management.

For purposes of statistical analysis, the facts recorded on the chart may be transferred in code to a Hollerith punch card.[1] These when punched can be rapidly sorted by mechanical means.

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1. For further information as to this method, readers are referred to the mimeographed pamphlet of the Committee on Records and Statistics of the American Society of Anesthetists, which is available for one dollar at room 1503, 745 Fifth Avenue, New York.

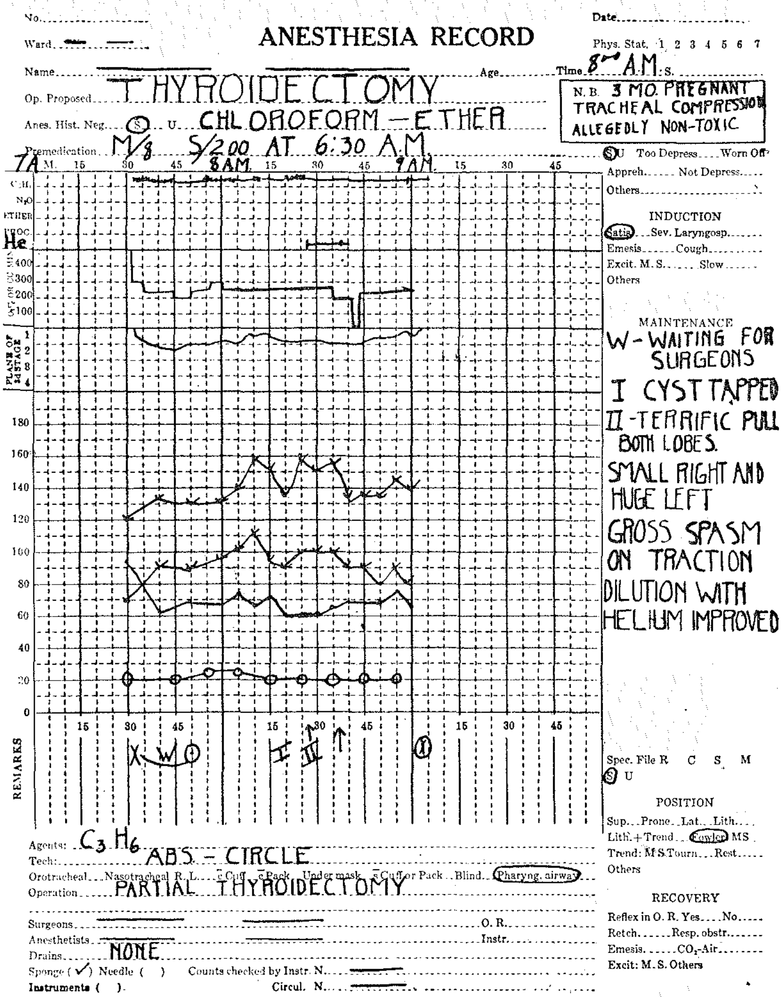

Fig. 1.—Anesthesia record blank as filled out in a case of thyroidectomy for nontoxic nodular goiter: The obverse.

Name [redacted] (Last Name) [redacted] (First Name) (Mr., Mrs., Miss) S C P Stud.

Address

M. F Age 37 Wt. 174 Ht. 5' 4" T. 98.6 P. 76 R. 20 B. M. R.

Hb 12.1 R. B. C. 4.2 W. B. C. 9.2 Sugar N. P. N. Others

SURGICAL CLINICAL DIAGNOSIS NON-TOXIC NODULAR GOITRE

PREOPERATIVE	POSTOPERATIVE
RESPIRATORY	
Rhinitis U. R. I. A. R. C. NONE	NONE Rhinitis Pharyng or Laryng. Br. or Tr.
Br. or Tr. Cough Hicc. Emphysema	Cough Obstr. O₂ want Hicc. Otitis media
Br. asthma Pleurisy Rales base	Collapse Part. Mass. Pulmonary edema
Pneumonia Lung abscess Empyema	Pleurisy Pulm. embolus Empyema Aspiration
Tbc.: Act. Bilat. Arrest. Obstr.	Pneum.: Hypost. Bron. Lobar Tbc.
Br. Hd. under 15" V. C. less 33% 33-66%	Time: Op. day 1-3 days 4-7 days 2nd wk. 3rd wk.
Others TRACHEAL COMPRESSION FROM ENLARGED THYROID	Others SURGICAL DYSPHONIA
CIRCULATORY	
Ht. dis.: Hyperten. or a. scler. Luetic NONE	NONE Tachycard. Bradycard. Arrhyth. Fibrill.
Rheum. Thyrotox. Congen. Gen. a.-scler.	Hem.: Moder. Sev. Marked B. P. fall Shock
Func. Cap.: I IIa IIb III Cor. dis.	Cor. emb. or thromb. Circ. failure Pericard.
Tachycard. Bradycard. Arrhyth. Fibrill.	Cerebral emb. or thromb. Emboli misc.
Shock Hypoten. Hyperten. B. P. 106/68	Time: Op. day 1-3 days 4-7 days 2nd wk. 3rd wk.
Others	Others
CENTRAL NERVOUS SYSTEM	
Headache Nervousness Irrat. NONE	NONE Headache Headache, post-L. P. Irrat.
Paresthesia Paralysis Neurosis Psychosis	Paresthesia Paralysis Psychosis Meningitis
C. N. S. Lues Br. tumor Cd. tumor Epilepsy	Time: Op. day 1-3 days 4-7 days 2nd wk. 3rd wk.
Others	Others
GASTRO-INTESTINAL	
N. & E. Abd. disten. Ascites NONE	NONE Disten. Parotitis Obstr.: Part. Compl.
Intest. obstr.: Part. Compl. early Compl. late	Ileus Peritonitis Hem. N. & E. (duration) 5 & 4
Infect. viscus Perf. viscus	Time: Op. day 1 1-3 days 4-7 days 2nd wk. 3rd wk.
Others	Others
GENITO-URINARY	
Retention Indwell. cath. NONE	NONE Retention Indwell. cath. Low kid. func.
Cyst. Pyel. Tbc. dis. Low kid. func.	Cyst. Pyel. Hematuria Uremia Anuria
Nephr.: Ac. Chr. Uremia Oliguria Anuria	Time: Op. day 1-3 days 4-7 days 2nd wk. 3rd wk.
Others	Others
METABOLISM	
Diabetes Diab. Gang. End. disfunc. NONE	NONE Diabetic disturb. Cachexia Dehydr.
Menopaus. syn. Obes. Wt. loss Dehydr.	Thyroid crisis Tetany Acid. Alk.
Thyroid Hyper. Hypo. Non-tox. Acid Alk.	Time: Op. day 1-3 days 4-7 days 2nd wk. 3rd wk.
Others	Others
OBSTETRICAL & GYNECOLOGICAL	
Preg. 3 MO. Primip. Multip. Premat. NONE	NONE Baby: Good Poor Still. Twins
Twins Toxemia Abort.: Infect. Non-infect.	Art. resp. Spont. resp Pain relief: Good Fair Poor
Tub. Preg. Dispropor. O.A. O.P. Breech	Post-partum hem. Post-part. tox. Sepsis
G.C. Salpingitis Uterine hem.	Time: Op. day 1-3 days 4-7 days 2nd wk. 3rd wk.
Others	Others
MISCELLANEOUS	
Malig. Anemia: S. P. Leukem. NONE	NONE Tech. Comps.
Enlarg. Thymus Lues Senil. Thy. Ad. non-Tx.	Miscellaneous
Inc. Cran. Press. Drug Add. Alc. Anoxia	Fever: 103+: Op. day 1-3 days 4-7 days 2 wk. 3 wk.
Oxyg. Ther. W.B.C. Fever Pain Inf. Ac. Chr.	Treatment: None Wang. suct. I. V. Fl. Subuc. Fl.
Others	Opiates Oxy. Ther. Trans. Trach. toilet
	Rect. Fl. Barb. CO_2 & air Vol. Hypervent.
	Others
	Pt. Seen Within 24 Hr.: Yes No
	Subsequent Visits
	Immed. cause death & time:

SUMMARY MUCH SORE THROAT WITH DYSPHONIA DID WELL

Fig. 1.—The reverse.

Records in Military Practice

By use of the code recommended by the educational committee of the American Society of Anesthetists, such a case record may be directly entered on the Hollerith punch card (3¾ by 7⅜ in.). The application of such a technic in military practice has been reported. This combination chart and record card appears in figure 2A.

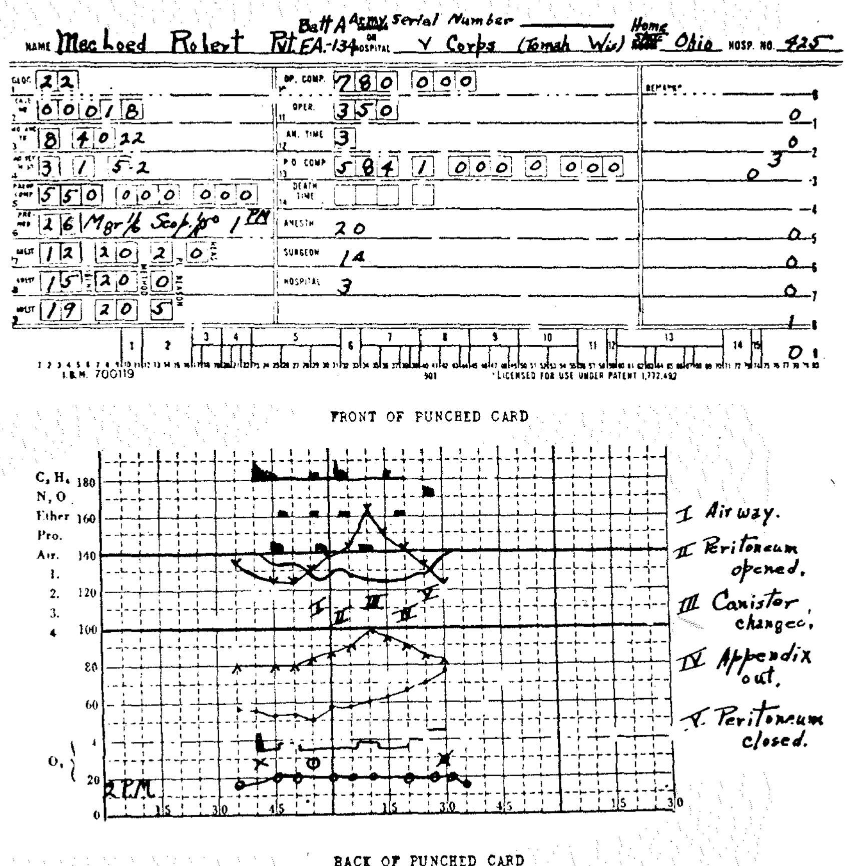

Fig. 2A.—Front and back of Hollerith punch card as filled out and punched in military practice.

CONSULTATION RECORD

Resuscitation and Oxygen Therapy Section

Date:............................

I. NAME OF PATIENT:..........................GRADE:....Age:....Ward:....

Consultation requested by........Med:....Dent:....Surg:....Pre:....Postop:....
Reason for Consultation:..
Diagnosis: ....

II. RESUSCITATION:

A. Maintenance of Resuscitation: — TIME
1. Airways: Natural...Artif: oral...nasal...endotr.... — Begin....End....
2. Manual: Sylvester...., Schaefer.... — " .... " ....
3. Inflation of chest: Closed CO_2 absorption technique.... — " .... " ....
4. Drinker-Collins Respirator — "Iron Lung" — " .... " ....

B. Maintenance of Cardiovascular System
1. Drugs used: ....
2. Intravenous fluids: Infusions.............., Transfusions................

III. OXYGEN THERAPY:

A. Method Employed	Flow/min.	TIME
1. BLB nasal mask................		Begin....End....
2. Catheter: nasal......, oral......		" .... " ....
3. Endotracheal		" .... " ....
4. Others		" .... " ....

IV. OTHER GASES — TIME

A. Helium — Method used:........... — Begin....End....

B. CO_2 — Method used:........... — " .... " ....

V. SUMMARY

A. Evaluation of treatment
1. Recovery.......... 2. Partially effective.......... 3. No effect..........

B. Reason for failure..

C. Recommendations ....

Anesthetist......................

Fig. 2B.—Record form for resuscitation and gas therapy used in an Army general hospital.

References

1. Lundy, J. S.: Keeping Anesthetic Records and What They Show, Am. J. Surg. **38**:16 and 25 (Jan.) 1924.

2. Tovell, R. M., and Dunn, H. L.: Anesthesia Study Records, Anesth. & Analg. **11**:37-41 (Jan.-Feb.) 1932.

3. Wangeman, C. P.: An Experiment in the Recording of Surgical and Anesthetic Data in Military Service, Anesthesiology **2**:179-185 (March) 1941.

4. Martin, S. J., and Makel, H. P.: Organization of a Section on Resuscitation and Oxygen Therapy, Army M. Bull., to be published.

NOTES

II

Physiologic Considerations

THE TRANSPORT SYSTEM

THE EXTENT of the knowledge of physiologic processes possessed by the anesthetist and by all persons dealing with acute disturbances of respiration and circulation will largely determine the value of their service to patients. An attempt has been made herein to simplify such knowledge and to confine consideration to the grosser aspects of the system of transport for oxygen, carbon dioxide and the drugs and fluids used to produce anesthesia and relieve pain or to counteract (if that be possible) the depressant and harmful effects of illness, injury and drug action. A thorough understanding of the transport system is essential to the care of patients. If the anesthetist is to prevent or to recognize and treat successfully many of the changes occurring in the physiologic activity of his patients, he must become familiar with the more intimate aspects of physiology in addition to those which follow. It is hoped that such a text as that of Best and Taylor (see reference, p. 22) may be available to physicians using this manual. Many of the details of biochemistry and of the autonomic nervous system and its reflex pathways are pertinent to the effective care and treatment of patients subjected to anesthesia and surgical procedure or to injury and illness.

In addition to the elementary exposition of the transport system presented in the following illustrations and comments, a further consideration of the two great components of this system, respiration and circulation, will be found under "Respiratory Emergencies," page 151, and "Circulatory Emergencies," page 161.

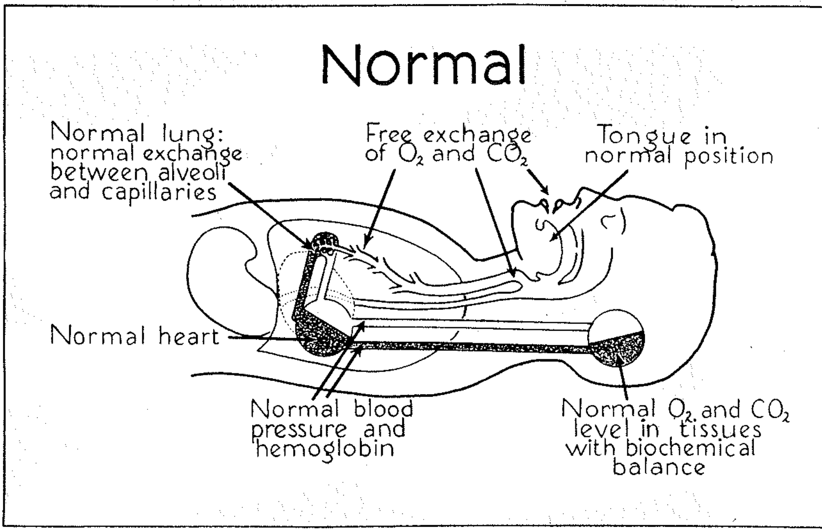

Fig. 3.—Ideal transport of oxygen, carbon dioxide and drug.

Of all substances required for life, oxygen is the most vital, yet the least possible to store in the body. Food can be withheld for days and water for hours, but complete lack of oxygen for more than a few minutes will be fatal or severely damaging to the organism. Likewise, feces may be retained for days and urine for hours, but total blockage of the excretion of carbon dioxide will be fatal in a very short time.

A normal heart and vessels, normal blood and normal lungs and air passages are the body's means of transporting oxygen to the tissues and carbon dioxide to the outside air. Any disturbance of the mechanism controlling transport, by drug or disease, or any interference with the air and blood channels, will disrupt the vital functions of the body's cells. The severity and rapidity of the cell damage will vary with the severity and rapidity of the interference with gas transport.

HELP NATURE TO MAINTAIN A NORMAL TRANSPORT SYSTEM.

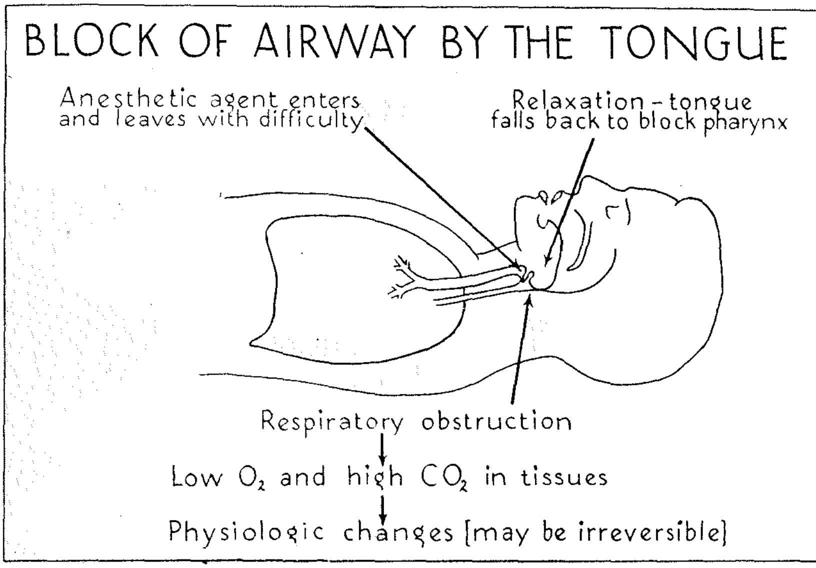

Fig. 4.—Gas transport obstructed by fallen tongue.

Derangement of several vital functions is a feature of depression from any cause, whether drug effect, disease or physiologic injury.

The respiratory and circulatory centers in the brain assume lowered levels of activity, there is lessened effort by the respiratory tract to rid itself of mucus and foreign bodies, and the laryngeal "watchdog"[1] becomes drowsy and may admit foreign material to the trachea.

The commonest danger of all lies in a lessening of muscle tone. The flaccidity of the tongue muscles in normal sleep causes partial obstruction, which is called snoring; in disease or during the action of any sleep-producing drug the more profound relaxation may result in severe or complete respiratory obstruction.

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1. Chevalier Jackson coined this term to describe the system of reflexes in the upper respiratory passages which prevent contamination of the lower.

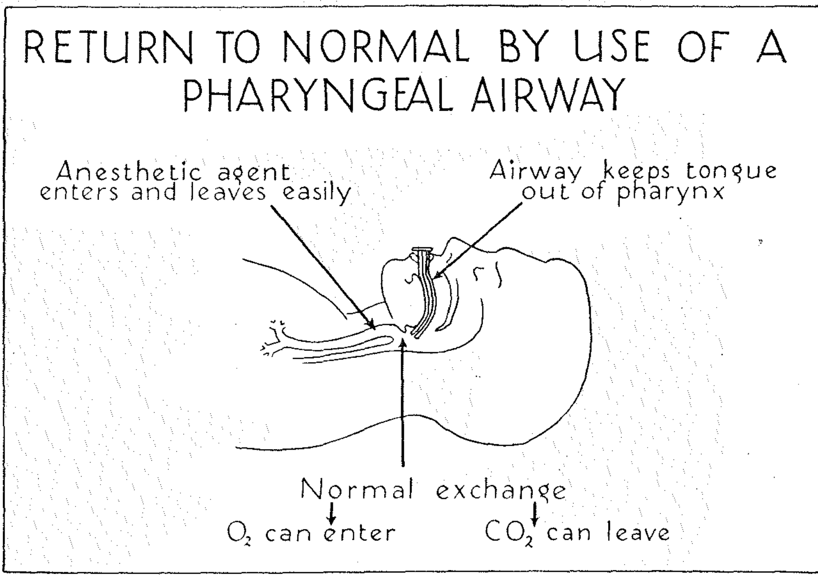

Fig. 5.—Restoration of gas exchange by means of an inserted pharyngeal airway.

When circumstances allow, the tongue may be replaced in a nearly normal position by turning the patient so that the tongue falls forward against the teeth.

Barring this, the tongue can be lifted forward by its attachments to the mandible, by lifting the latter upward at the angles of the jaw.

Sometimes an artificial pharyngeal airway is necessary to restore normal relationships and open up a free passage for air.

(See also under "General Anesthesia," p. 25.)

NOISY BREATHING IS OBSTRUCTED BREATHING, BUT OBSTRUCTED BREATHING MAY NOT BE NOISY.

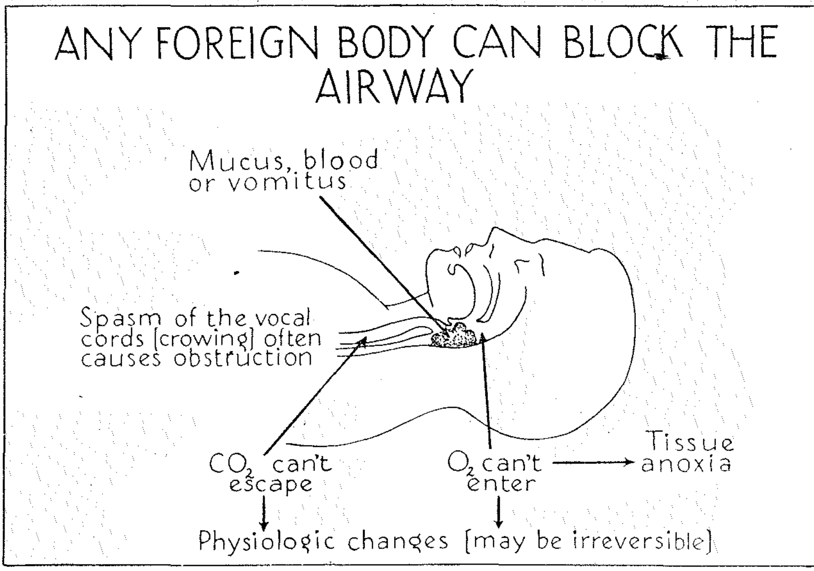

Fig. 6.—Obstruction due to spasmodic reaction to irritating foreign body in airway.

Simple obstruction of the air passages by a foreign substance is common. More frequently obstruction occurs because the half-awake laryngeal "watchdog," excited by the intruder, springs into overactivity, with mild, severe or complete laryngospasm as the result. The spasm may be all out of proportion to the stimulus applied. The lodging of a small tooth on the cords may not of itself block the glottis, but the laryngospasm may be complete and fatal.

BE GENTLE IN REMOVING FOREIGN MATERIAL FROM THE LARYNX.

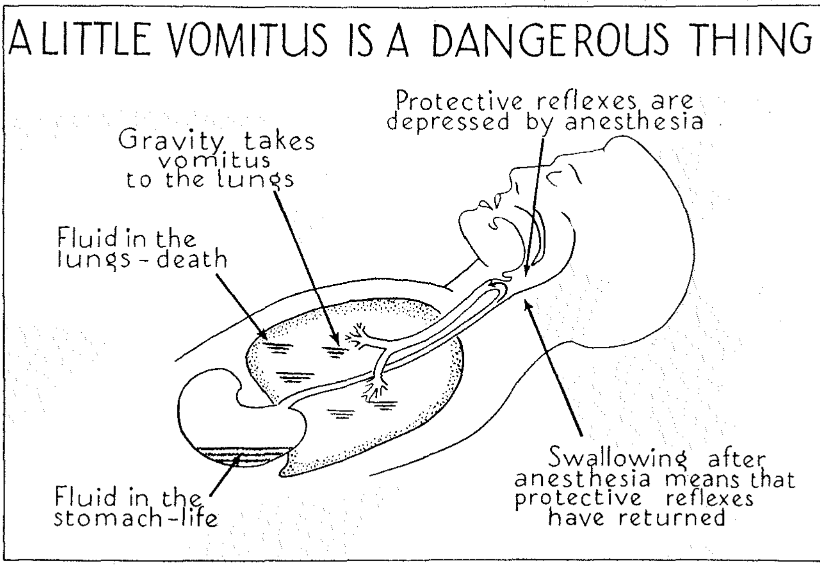

Fig. 7.—Anesthetic depression of laryngeal sensitivity allows vomitus to be drawn by gravity into the lungs.

During induction of anesthesia, or whenever anesthesia is lightened, a little regurgitation may occur which can pass unnoticed. When the laryngeal "watchdog" is inactivated by deeper anesthesia, this vomitus may freely enter the trachea and bronchi without exciting the usual laryngeal outcry and attempt at closing the entrance to the trachea.

This silent aspiration of vomitus (or blood) can be detected only by observation of the chest movement and of the color of the skin.

UNRECOGNIZED VOMITING MAY PROVE FATAL.

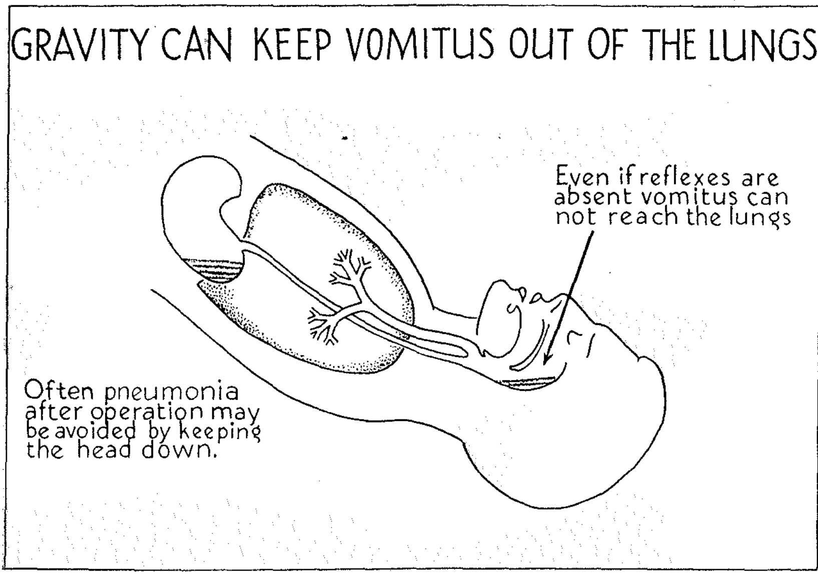

Fig. 8.—This position keeps vomitus out of lungs.

In deep anesthesia (and all depressed states) there is often no warning laryngospasm or noisy respiration to tell one to remove foreign substances.

When possible, the patient should be kept on his side till the laryngeal "watchdog" can take over the guardianship of the air passages. This may be hours after the administration of the anesthetic stops. There must be supervision till the danger is past. Suction drainage is useful.

USE GRAVITY TO HELP, NOT HINDER, YOU.

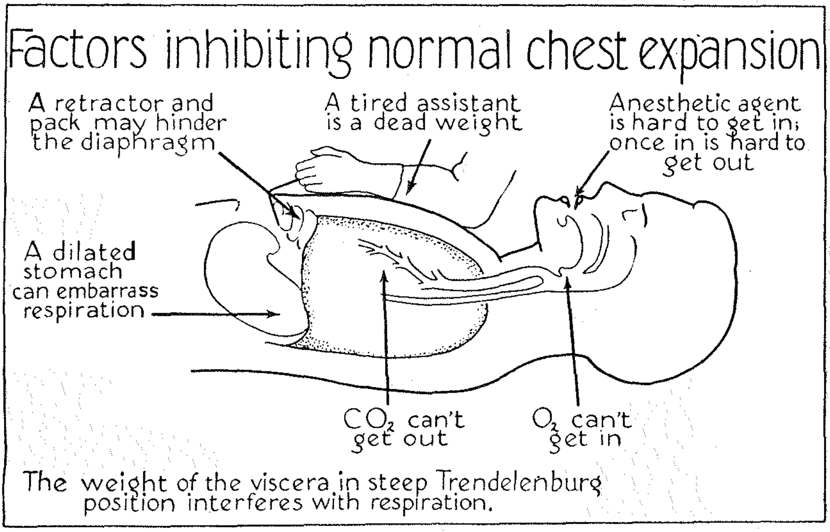

Fig. 9.—External factors the anesthetist must watch for.

Every one has some appreciation of the increasing paralysis of the respiratory muscles that accompanies increasing depth of anesthesia. Morphine, the barbiturates and like agents will have just as much effect as inhaled anesthetics in comparable doses. When the pleural cavity is opened during operation (or by a wound), the normal negative pressure surrounding the lungs is lost. The lungs tend to collapse. The remedy is artificial exchange.

The sketch points out several other inhibitors of effective lung expansion. Often they are all acting at once, but any one can be a danger.

THE GOOD ANESTHETIST OBSERVES THE WHOLE PATIENT, NOT JUST THE HEAD.

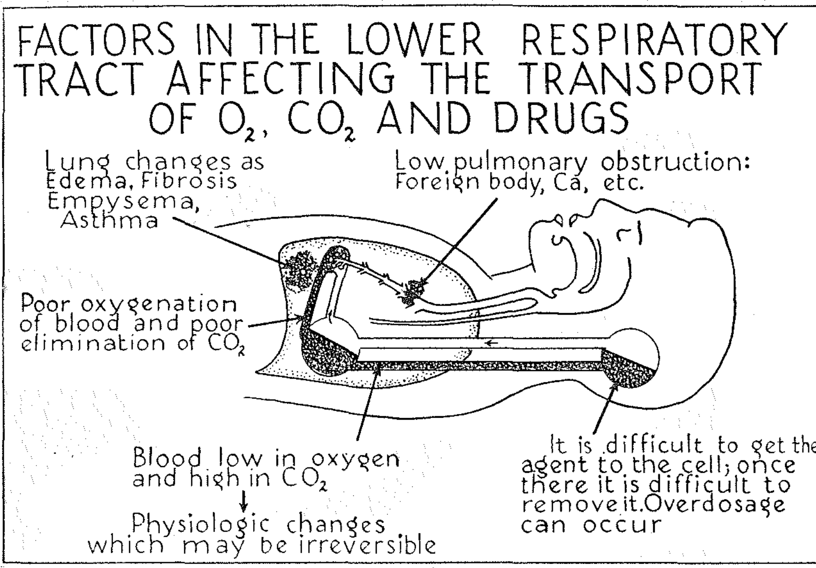

Fig. 10.—Internal sources of danger.

The obvious causes of obstruction in the lower respiratory tract are the commonest, but the obscure ones can be more dangerous.

When it is unusually difficult to get the anesthetic agent in, look for more trouble in getting it out. Such a condition may be the only evidence of pulmonary fibrosis, emphysema, incipient asthma or pulmonary edema.

OBSTRUCTION AT THE ALVEOLAR MEMBRANE MAY REQUIRE PROLONGED ARTIFICIAL RESPIRATION.

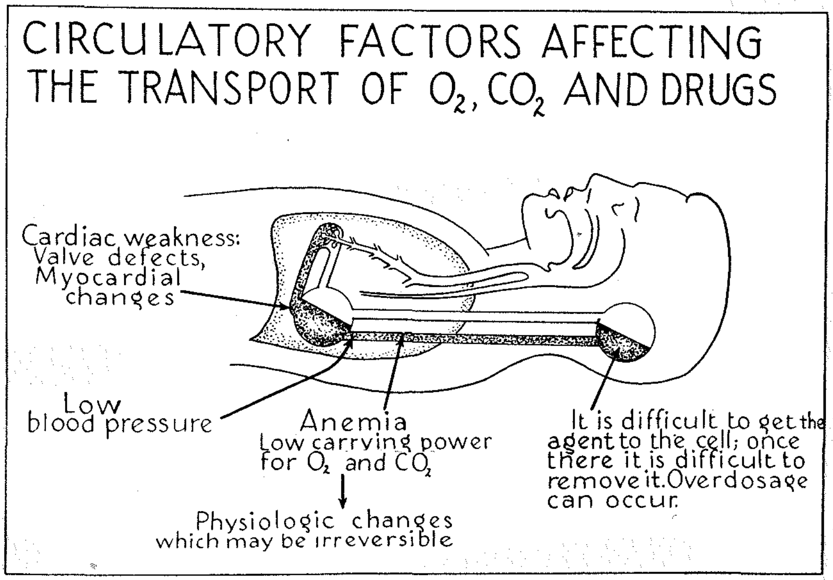

Fig. 11.—Further internal sources of danger.

The circulatory system is the vital link in the transport system beyond the alveolar membrane.

Myocardial or valvular defects and low blood pressure have the same net effect on the movement of oxygen and carbon dioxide as have depression of respiratory function and obstruction of respiratory passages.

Severe anemia may be particularly dangerous, as there must be at least 5 Gm. of reducible hemoglobin per hundred cubic centimeters of blood for visible cyanosis. Other signs, e. g., pulse changes, must be relied on to warn of oxygen want in such patients. With inefficient circulation, the same difficulty with "getting the agent in," and with the elimination of it, will be experienced as when there is obstruction at the alveolar membrane.

THE ANESTHETIST MUST BE A SKILFUL DIAGNOSTICIAN AS WELL AS A CLEVER TECHNICIAN.

WANT OF OXYGEN AND EXCESS OF CARBON DIOXIDE

The common causes of these two conditions may be summarized as follows:

1. An increase in carbon dioxide or a deficiency in oxygen in the inspired atmosphere.
2. Respiratory obstruction from any cause.
3. Any mechanical interference with respiratory exchange, such as abdominal packs, intercostal paralysis, etc.
4. A decrease in functional alveolar surface.
5. Anemia.
6. Poisons, such as carbon monoxide.
7. Heart failure.
8. Excessive use of depressant drugs, with resultant decreased minute volume respiratory exchange, or obstruction of the respiratory tract.
9. Circulatory depression, such as shock.

TABLE 1.—*An Outline of Symptoms and Signs of Oxygen Want in Order of Increasing Severity*

	MILD		MODERATE		SEVERE	
Psychic	Overconfidence	Impaired vision; Impaired judgment	Dizziness; Anxiety	Air hunger	Weakness; Delirium	Coma
Gastrointestinal		Nausea	Retching	Vomiting		
Sensory		Headache	Precordial pain			
Respiration: Rate	Periodic	Marked increase	(Apnea after oxygen is restored)		Depression	Arrest
Respiration: Depth	Irregular	Slight increase			Depression	Arrest
Blood Pressure	Slight rise or fall		Acute rise		Disappearance	
Pulse Rate	Increased	Sometimes arrhythmia		Slow, full, bounding		Cessation
Musculature		Incoordination	Twitching; Spasms of muscle groups		Convulsions	Relaxation
Color	Cyanosis depends on hemoglobin, type of skin and peripheral circulation					
Pupils					Dilatation and fixation	

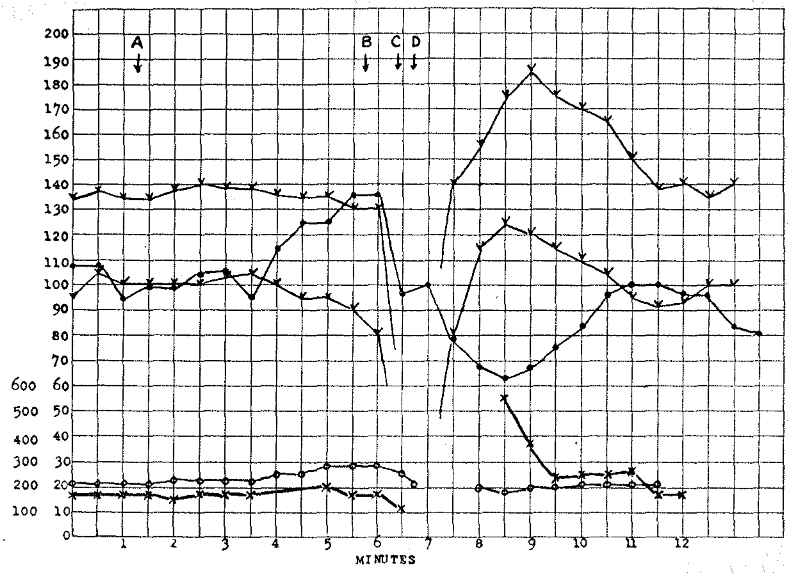

Fig. 12.—Record of changes accompanying acute oxygen want. Blood pressure V—V. Pulse rate ●—●. Respiratory rate o—o. Tidal volume x—x. The column of figures on the extreme left represents tidal volume in cubic centimeters. The second column of figures represents blood pressure in millimeters of mercury, and pulse and respiratory rates per minute.

A woman 25 years old, after she had been under nitrous oxide anesthesia for a minor pelvic operation for thirty-five minutes, was caused to inhale pure nitrous oxide through an endotracheal airway from a recording spirometer for approximately five minutes (*A-D*). At *B* the pulse was weak and the color only slightly cyanotic. At *C* the blood pressures could not be read. At *D* respiration had almost ceased. The chest was then inflated twice with pure oxygen. After the period of apnea lasting thirty seconds, note the rise in blood pressures and tidal volume and the decrease in pulse rate. Premedication (morphine sulfate 1/8 grain [8.1 mg.]; scopolamine hydrobromide, 1/200 grain [1.3 mg.], and paraldehyde, 1 ounce [31 Gm.] in this case) frequently thus modifies the typical "oxygen crisis" seen in laboratory animals subjected to acute oxygen want.

Figure 12 represents the evidence of severe oxygen want, but lesser degrees are common, and are easily recognized if color, pulse and blood pressure are under constant observation.

Oxygen want of every degree is harmful to the patient—correct it at once. Oxygen is a patient's most vital need.

TABLE 2.—*An Outline of Symptoms and Signs of Carbon Dioxide Excess in Order of Increasing Severity*

		Mild	Moderate	Severe
Psychic		Discomfort	Dizziness	Unconsciousness
Sensory		Local irritation to upper part of respiratory tract		
Respiration	Rate	Slight or no increase	Depressed	Arrested
	Depth	Markedly increased	Depressed	Arrested
Blood Pressure	Systolic	Increased	Increased markedly	Fall
	Diastolic	Increased	Increased moderately	Fall
Pulse Rate			Moderate increase	
Musculature		Twitching	Spasms of muscle groups	Convulsions
Color		Pink due to peripheral dilatation unless oxygen want is added		
Pupils			Variable	

Changes in pulse, respiration and blood pressure, even more marked than those shown in figure 13, may be seen in the course of what seems to be normal anesthesia. If oxygen lack can be ruled out, do not fail to rectify conditions which may be causing carbon dioxide excess.

All too commonly it is not recognized that oxygen want and carbon dioxide excess occur independently as well as together. In obstruction or depression of either the respiratory or the circulatory transport system, the two occur as features of asphyxia.

When pure oxygen is being added to the anesthetic mixture, it is easy to overlook the accumulation of carbon dioxide, as in the use of semiclosed anesthetic systems.

Again, when carbon dioxide is being efficiently removed by an absorbent, oxygen want may be acting alone.

CARBON DIOXIDE IS A WASTE PRODUCT. DO NOT HINDER ITS EXCRETION WITHOUT A PURPOSE IN DOING SO.

DEPLETION OF CARBON DIOXIDE DOES *NOT* CAUSE SHOCK.

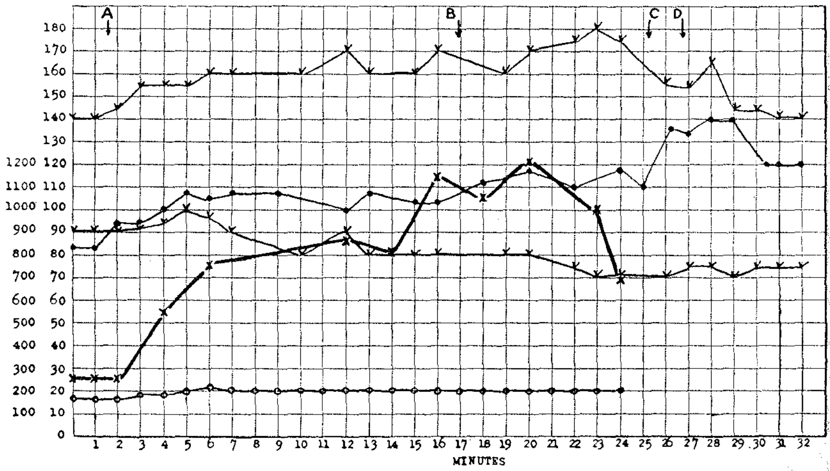

Fig. 13.—Record of changes occurring during the inhalation of excess carbon dioxide. Blood pressure V—V. Pulse rate ●—●. Respiratory rate o—o. Tidal volume x—x. The column of figures on the extreme left represents tidal volume in cubic centimeters. The second column of figures represents blood pressure in millimeters of mercury, and pulse and respiratory rates per minute.

A woman 26 years old, after seventy minutes of nitrous oxide anesthesia for arthrodesis of the ankle, was caused to rebreathe a nitrous oxide-oxygen mixture through an endotracheal airway from a recording spirometer without soda lime for a period of approximately twenty-four minutes (*A-C*). At *B* some oxygen was added, somewhat reducing the carbon dioxide concentration which had accumulated. At *C* the rebreathing was discontinued and the patient allowed to breathe air. No spirometer record was obtained from this point. At *D* the patient was awakening. Note the rise in systolic blood pressure and pulse rate, and the extreme rise in tidal volume while the respiratory rate was only slightly increased. The beginning depression characteristic of increasingly high carbon dioxide concentrations is seen in the fall in tidal volume at the end. The premedication in this case was morphine sulfate, ¼ grain [0.016 Gm.], and scopolamine hydrobromide, 1/100 grain [0.65 mg.].

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TREATMENT OF RESPIRATORY OBSTRUCTION

Obstructed breathing is the beginning of trouble for the anesthetist and his patient. No other single complication is so frequently encountered during depressed states. Respiratory obstruction is recognized by one's ears and eyes—diagnostic tools so simple as to make it seem ridiculous to speak of "learning" the technic of diagnosis. And yet the young anesthetist cannot do better than to study the breathing of—

1. Normal persons, himself included.
2. Every anesthetized patient he encounters.
3. Patients who have received depressant drugs.
4. Patients with diseases of the throat and chest.
5. Patients with diseases of the central nervous system.
6. Patients who have been injured.

By careful observation of all these, the anesthetist ought to strive for a sixth sense—an instinctive and immediate recognition of minor degrees of interference with the rhythmic passage of air to and from the lungs. He will observe that normal breathing at rest is almost inaudible and that respiratory movements of the chest and abdomen are perfectly symmetric and synchronous. Any variations from normal, he must learn to interpret in terms of possible obstruction.

Many types of abnormal breathing and even some types of obstruction are not subject to immediate relief. However, the abnormalities usually encountered by the anesthetist may be relieved by proper technical maneuvers.

Tracheotomy has long been employed for the relief of respiratory obstruction. In the case of a new growth invading the upper air passages, it is still a life-saving measure. In the majority of instances, however, early recognition and prompt treatment of a simpler sort will restore an adequate air passage. Delay adds difficulty in treatment and creates increasing disturbance of physiologic functions.

FREE BREATHING IS ESSENTIAL TO NORMAL LIFE

SIMPLE MANEUVERS FOR THE RELIEF OF OBSTRUCTION

1. Place the patient in a semiprone and head low position.
2. Try alterations of position that may help. This includes moving the head from side to side, as well as flexion and extension.
3. With the flexed index fingers behind the angles of the patient's mandible, slide the lower jaw forward (and with it the tongue) on the upper teeth as far as possible and hold it in this position by light upward pressure under the chin.
4. With a towel or other fabric, grasp the tongue directly between thumb and finger and bring it forward.
5. When depression results in diminution or absence of pharyngeal or laryngeal reflexes, an artificial airway may be needed.

NOTES

ARTIFICIAL AIRWAYS

It will be found easier to maintain a free airway and quiet respiration when the head bears its normal relation to the trunk. Most persons carry the head a little forward; pillows maintain this forward position during sleep or general anesthesia. It is unnatural to have the head tilted sharply backward, as is often seen when too flat a pillow, or none at all, is used.

Oropharyngeal Airway

Figure 14 shows the oropharyngeal airway in place with the flange outside the lips, the portion between the lips and

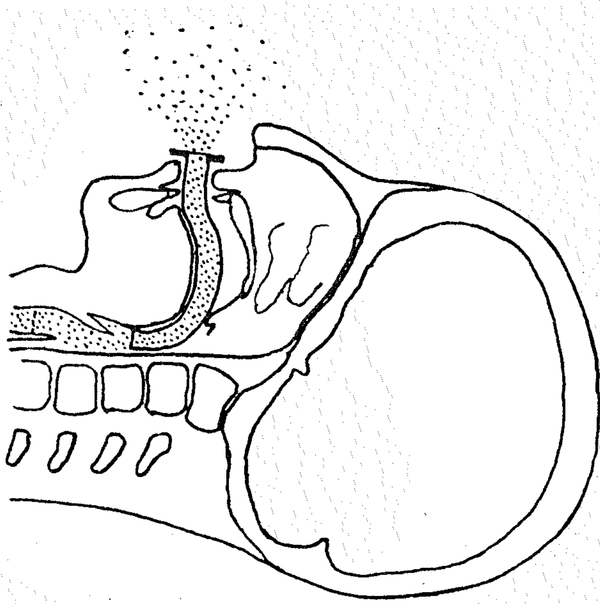

Fig. 14.—Oropharyngeal tube in place.

the teeth straight, the remainder curved up and back, following the curve of the palate and tongue, changing the original direction a full 80 to 90 degrees. It may be of composition metal or heavy wire as long as the curve is correct.

Nasopharyngeal Airways

To make a satisfactory breathing tube to pass through one nostril into the lower part of the oropharynx, and so below the base of the tongue, one need only cut a Magill tracheal tube to the desired length.

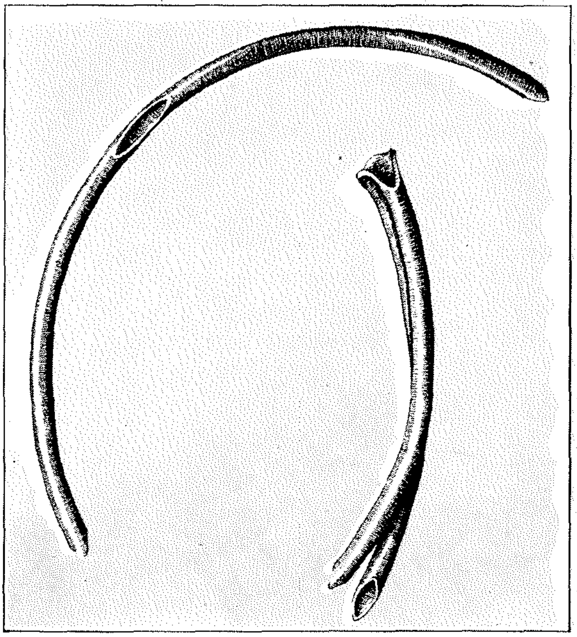

Fig. 15.—Nasopharyngeal airway made from rubber tubing such as that used for fountain syringes.

If a tracheal tube is not available, one can usually find a length of commercial rubber tubing such as is used with fountain syringes. If it has been rolled in a coil a foot in diameter, so much the better. Select and cut off a foot (30 cm.) of such tubing. As it lies curved on the table, cut a long fenestrum in the upper wall midway of its length, removing one-half the diameter. Then kink the tubing at the fenestrum so that the two halves lie parallel, curved alike and held together by a thin piece of the tube wall opposite where the opening was cut. Now cut off the two free ends at an angle to produce a bevel and at a length to reach from the external nares to the desired point in the pharynx. This is just above the glottis in a patient whose reflexes are abolished; otherwise it is less deeply placed. Now lubricate both ends thoroughly and insert gently through the nostrils with the concavity of the curve down. Such a double airway, if of proper length, provides adequate breathing space (fig. 15).

ENDOTRACHEAL AIRWAY

The passage of a tube into the trachea insures a perfect airway if certain precautions are observed. This procedure is useful during resuscitation. The endotracheal tube is also employed as a means of administering drugs by inhalation.

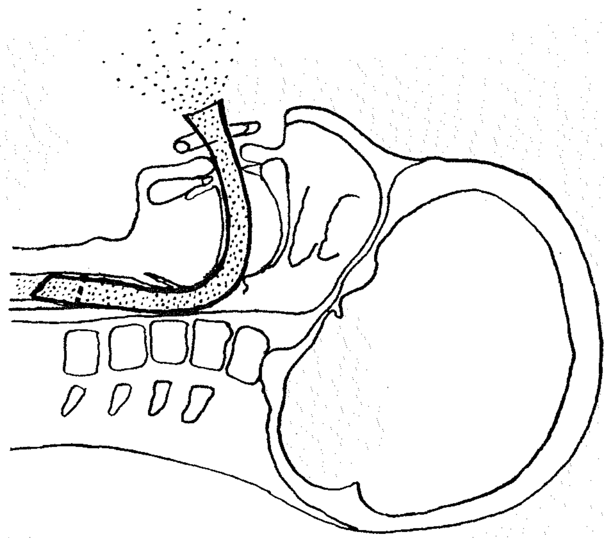

Fig. 16.—Endotracheal airway in place.

It is used to provide a free airway during the profound depression induced by nonvolatile drugs, because:

1. In operations on the head and neck, the anesthetist and his apparatus are removed from the surgical field. This frees the surgeon from interference and makes asepsis possible. It has revolutionized operating conditions in the upper air passages.
2. Foreign substances can be prevented from entering the trachea.
3. Pus, blood, mucus or vomitus may be removed from the trachea by passing a suction catheter through the tube.
4. Intubation makes for better relaxation during abdominal operations.
5. Intubation facilitates the control of the intrapulmonary pressure; pneumothorax can be prevented, and atelectasis can be remedied.
6. Obstruction from spasm of the glottis can be prevented by intubation.

Such tubes can be made of spiral metal coils, semirigid compositions, mineralized rubber or ordinary rubber tubing.

Orotracheal Intubation

Intubation through the mouth is usually performed by direct laryngoscopy. There must be full relaxation of the mandible and suppression of the pharyngeal and laryngeal reflexes. Such conditions are often present in the candidate for resuscitation.

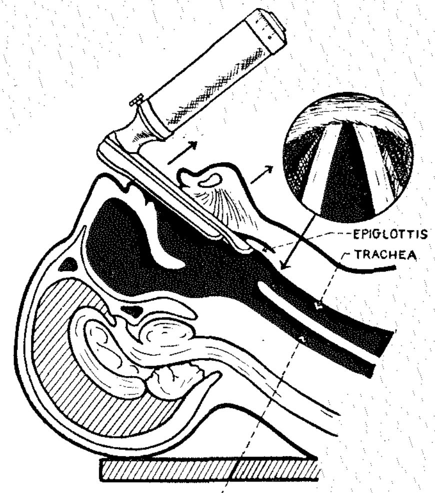

Fig. 17.—Placing the orotracheal airway.

The laryngoscope is passed down the dorsum of the tongue until its beak is under the epiglottis. Then the instrument is lifted in the direction of the arrows to expose the glottis. The tube, lubricated with petrolatum or a soluble jelly, is passed in.

Use as wide a tube as will pass without force.

Lay it alongside the patient's head beforehand and make sure that when it is passed, its end will not lie below a point midway between the cricoid and the second costal cartilage.

When the tube is in place, insert a roll of gauze or a wooden spool between the teeth to prevent it from being bitten.

If a gas-tight setup is required, an inflatable cuff should be used on the tube or a length of gauze should be packed around it in the pharynx. In the treatment of extensive wounds about the face and air passages, such a tube and pack may prove life saving not only in providing free breathing but also in permitting adequate packing to stop hemorrhage.

A safety pin through the distal end of the tube or a metal fitting prevents it slipping out of reach.

NASOTRACHEAL INTUBATION

Intubation through the nose is performed with a curved rubber Magill tube, as large as will pass through a nostril without the use of force. Cocaine or other anesthetic solution may first be sprayed through the nostrils during inspiration. This diminishes reflex activity and shrinks the mucous membranes, thus increasing available space.

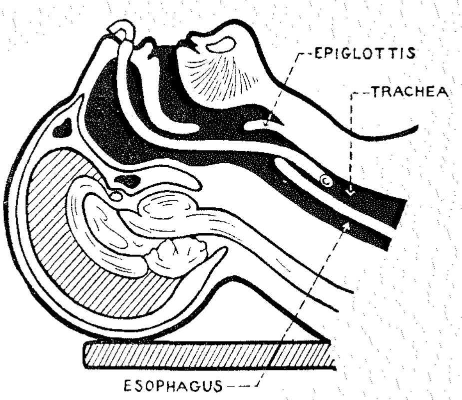

Fig. 18.—Placing the nasotracheal tube.

Intubation by Direct Vision.—Laryngoscopy is performed. The tube is passed through the nose into the field of vision and inserted into the glottis. If this cannot be done otherwise, it is permissible to place the tube in the glottic opening with forceps.

Intubation by the "Blind" Technic.—A curved tube (an arc of proper length of a circle—8-15 inches [20-38 cm.] in diameter) is passed into the pharynx through the nose. The anesthetist listens to the breath sounds through it, and follows them until the tube enters the glottic opening. Changing the degree of flexion or extension of the head modifies the relation of the tube to the glottis anteroposteriorly. Rolling the tube between thumb and finger modifies relation laterally. If the tube is long enough to reach from the nose through the glottis, it must be in the trachea if when passed to its full length breathing still takes place through it. When laryngoscopy cannot be performed, a patient can be intubated in this way.

NOISY BREATHING IS OBSTRUCTED BREATHING, BUT OBSTRUCTED BREATHING MAY NOT BE NOISY.

Warnings

Don't use the nasal route if there is nasal distortion or sepsis.

Think before you choose the route of intubation.

Remember that even laryngeal tubes can kink and become obstructed.

Never fail to observe respiration and circulation, even if the patient is intubated.

Never leave a patient after removing a tube, until you are sure that normal, unobstructed respiration has been reestablished. A pharyngeal airway may be necessary for a short period following extubation. If reflexes are active, laryngospasm may occur as a result of extubation. Oxygen may be helpful.

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SUBTLETY AND NOT FORCE IS THE KEY TO INTUBATION.

III

Pharmacologic Considerations

BECAUSE of the importance of the derivatives of opium and barbituric acid to the anesthetist, a detailed consideration of these agents is reprinted in full as it appeared in the pamphlet of the American Medical Association Exhibit for 1938.

For the sake of brevity, the pharmacology of other drugs used to produce comfort and to promote safety has been presented in tabular form. This has been done with a full realization of the inadequacy of such a method. The table of volatile and gaseous agents is copied without important changes from the American Medical Association pamphlet of 1938. The tables of nonvolatile drugs list a majority of the agents that are used by the anesthetist and, in addition, carbon dioxide, which was omitted in the exhibit table. To each drug has been assigned a customary range of dosage by a stated route of administration for the average patient. The potentially hazardous results of dogmatic tabulation are appreciated. *Complete individualization of choice of drug and dosage is the only path to safety.*

In any event, the outstanding desirable effects of each drug are mentioned later in connection with the technics of drug administration, while under "Complications" (p. 142) the physician is warned of the more important undesirable by-effects to be expected. It is hoped that the text of Gilman and Goodman (see references, p. 46) or a similar reference book may be available to those who use this manual.

OPIUM DERIVATIVES

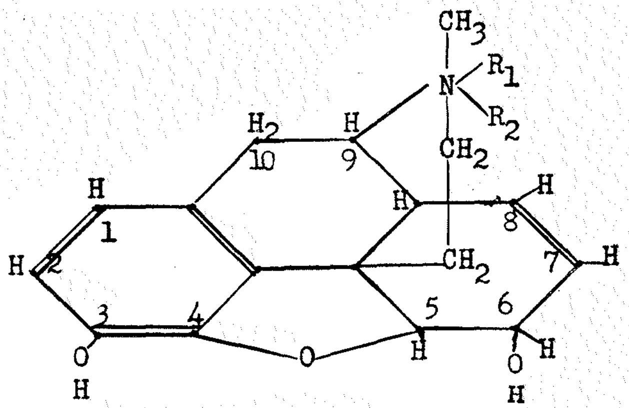


Fig. 19.—The structural formula of morphine. Below is a comparison of morphine with certain derived alkaloids, showing how they differ in chemical structure. The numbers that head the columns in the table below refer to the numbers that designate position in the structural formula.

	Position			
	3	6	7	8
Morphine	OH	OH	H	H
Dihydromorphinone (dilaudid)	OH	=O	H_2	H_2
Ethylmorphine (dionin)	OC_2H_5	OH	H	H
Methylmorphine (codeine)	OCH_3	OH	H	H

Apomorphine (morphine —H_2O): a rearrangement of the morphine molecule: ether linkage eliminated, –OH groups in positions 3-4. N-containing ring shifts to position 8.

Pantopon (Omnopon), N.N.R. 1930 (omitted from 1931 on): a mixture of the hydrochlorides of all natural alkaloids (about 20) of opium, comprising about 20 per cent of the crude drug; contains 50 per cent morphine. One-third grain of pantopon contains only 1/25 grain less morphine (base) than 1/4 grain of morphine sulfate.

Alkaloidal Salts

All the water-soluble salts (hydrochlorides, sulfates, phosphates, acetates, etc.) of the basic alkaloids are formed by the addition of the acid radical to N in the R_1 and R_2 positions.

Solubilities

Alkaloids (bases). Practically insoluble in water; soluble in lipoid solvents.

Salts. Soluble in water; insoluble in lipoid solvents.

Administration

Enteral. These derivatives are absorbed by all mucous surfaces, including buccal mucosa (also abraded skin surface).

Subcutaneous. Codeine and apomorphine are most rapidly absorbed after subcutaneous administration; morphine and dilaudid, less rapidly. (Codeine salts are painful if concentrated.)

Intravenous. The injection must be slow (two to three minutes) to avoid circulatory collapse or respiratory arrest.

Fate and Elimination

Morphine. Morphine is stored primarily in muscles, from which it is slowly liberated.

(*a*) Elimination: From 80 to 90 per cent is excreted in urine, both as free morphine and in "combined" forms. It is generally believed that 5 to 10 per cent is eliminated in feces. Only traces are excreted into the stomach after hypodermic administration; therefore repeated gastric lavage following poisoning by parenteral administration is of no value. Saliva shows a trace and milk a trace (?).

(*b*) Destruction: In view of newer evidence relating to elimination, no definite statements regarding the destruction of this narcotic can be made.

Codeine. Eighty per cent is eliminated in urine; traces, in feces; the remainder cannot be recovered.

Narcosis

The objective and subjective depression obtained with morphine, dilaudid and codeine is not identical with, and does not parallel entirely, the analgesic action of these derivatives.

The duration of narcotic action shows such individual variation as to make definite statements unreliable. If the drug is administered intravenously, slowly, the maximum subjective narcosis is reached in about three minutes; subsequently the effect is similar to that obtained sixty minutes after subcutaneous administration.

TABLE 3.—*Order of Decreasing Narcotic Action, with Subcutaneous Doses Which Will Produce Equivalent Analgesia*

	Maximum Narcotic Action (May continue at same level)
1. Morphine, 0.010 Gm. (1/6 grain) Pantopon, 0.015 Gm. (1/4 grain).............	30-60 min. after injection
2. Dilaudid, 0.001-0.002 Gm. (1/64-1/32 grain)....	30-60 min. after injection
3. Codeine, 0.064 Gm. (1 grain)................	15-45 min. after injection

Apomorphine hydrochloride 0.001-0.002 Gm. (1/64 to 1/32 grain) (subemetic) almost equals morphine in narcotic action, although probably less analgesia is obtained. In the dosage indicated, it is of particular value in combating the delirium occasionally caused by scopolamine.

EUPHORIA

A pleasurable subjective sensation and desire for repetition is present in decreasing order with:

1. Morphine
2. Dilaudid
3. Codeine

The tendency to addiction following repeated administration is in the same order.

ANALGESIA

If the *ordinary clinical* doses of the opium derivatives are administered, the order of decreasing analgesic efficiency is:

1. Dilaudid .... 0.002-0.003 Gm. (1/32-1/20 grain.)
2. Morphine .... 0.010-0.020 Gm. (1/6-1/3 grain).
3. Codeine .... 0.032-0.064 Gm. (1/2-1 grain).

If these drugs are administered intravenously in the same dosages, the peak of analgesic action is reached in fifteen minutes with all drugs, and the duration of analgesic action is shorter.

Pantopon differs from morphine only in that it is more effective in relieving pain due to smooth muscle spasm. (Isoquinoline alkaloids antagonize this spasm.)

TABLE 4.—*Approximate Equivalent Doses to Obtain Same Degree of Analgesia*

	Maximum Analgesia	Duration of Analgesic Action (Diminishing after maximum is reached)
Morphine, 0.010 Gm. (1/6 grain)..	60-90 min. after injection	3 -5 hr.
Codeine, 0.064 Gm. (1 grain)....	30-60 min. after injection	1½-2 hr.
Dilaudid, 0.001-0.002 Gm. (1/64-1/32 grain)...............	90 min. after injection	2½-3 hr.

RESPIRATION

All derivatives of opium reduce the minute volume of respiration, owing principally to decrease of respiratory rate, although tidal volume is diminished with larger doses.

The respiratory mechanism is rendered less sensitive to both chemical (carbon dioxide, acids) and nervous (reflex) stimuli.

A rise in alveolar and blood carbon dioxide follows ordinary doses. With large doses an uncompensated carbon dioxide excess develops.

Asphyxia occurs in proportion to reduction in the minute volume.

The order of decreasing depressant activity on respiration and the cough reflex (ordinary clinical doses) is as follows:

1. Morphine
2. Dilaudid
3. Codeine

CIRCULATION

Morphine (Subcutaneous Administration).

(*a*) Heart Rate: A normal heart rate is usually increased (reflexly); it may be decreased later.

A fast heart rate is usually reduced. This may be due to central vagal stimulation and diminished metabolism.

(*b*) Blood Pressure: This is unchanged by ordinary doses, but may be reduced by large doses owing to depression of the vasomotor center, asphyxia or reduced muscle tonus.

(*c*) Peripheral Vessels: These vessels are dilated, permitting an increased flow of blood.

(*d*) Splanchnic Vessels (Intestine, Spleen, Kidney, etc.): These vessels are constricted by ordinary doses.

(*e*) Cerebral Vessels: A dilatation of meningeal vessels is the rule, with or without an associated increase in intracranial pressure, depending on the volume flow of blood and other factors.

(*f*) Coronary Vessels: There is an increased coronary blood flow.

Other Derivatives. The effects do not differ particularly from those described for morphine. Codeine, if given intravenously, is apt to produce an anaphylactoid reaction (low blood pressure, etc.).

Gastrointestinal Effect

All these derivatives have a constipating effect (morphine may double the time required for the passage of a meal through the gastrointestinal tract). Any one of them may produce nausea and vomiting.

In order of decreasing activity on the intestine and production of side actions, the derivatives stand as follows (ordinary clinical doses):

1. Morphine
2. Pantopon
3. Dilaudid
4. Codeine

(Pantopon has a questionable superiority over morphine.)

Adjuvants

Scopolamine, if given in conjunction with morphine in the ratio of 1:25, antagonizes almost completely the respiratory depressant effect of morphine in the adult.

Atropine is less effective than scopolamine for this purpose, and ordinary doses are too small.

The respiratory depression produced by opium derivatives is greatly accentuated by small doses of barbiturates which in themselves give little evidence of a depressant action.

Treatment of Poisoning (Acute)

1. Provide an adequate airway (p. 25).
2. Augment respiratory exchange artificially (p. 153). (A mechanical respirator is desirable.)
3. Provide fluids and nourishment (dextrose intravenously).
4. Catheterize when necessary.
5. Cleanse the respiratory tract when necessary (p. 152).
6. Stimulants, such as coramine (a 25 per cent solution of pyridine betacarboxylic acid diethylamide), may be tried. They may be added to the fluids given intravenously.

BARBITURIC ACID DERIVATIVES

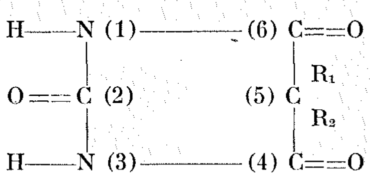


Fig. 20.—The structural formula of barbituric acid. Following is a comparison of certain barbituric acid derivatives, showing how they differ in chemical structure. The barbituric acid derivatives are listed in the order of decreasing duration of action. The numbers which head the columns in the table below refer to the numbers that designate position in the structural formula.

				(5) (R1	R2)	(1)	(2)
	LONG	Phenobarbital (luminal)....	U.S.P.	ethyl	phenyl		
	LONG	Barbital (medinal; veronal).	U.S.P.	ethyl	ethyl		
Increase	INTER-MEDIATE	Dial......................	N.N.R.	allyl	allyl		
	INTER-MEDIATE	Ipral......................	N.N.R.	ethyl	isopropyl		
	INTER-MEDIATE	Calcium					
	INTER-MEDIATE	Sodium					
	INTER-MEDIATE	Alurate....................	N.N.R.	allyl	isopropyl		
DURATION	INTER-MEDIATE	Neonal....................	N.N.R.	ethyl	n-butyl		
	SHORT	Nostal....................	N.N.R.	bromallyl	isopropyl		
	SHORT	Amytal....................	N.N.R.	ethyl	isoamyl		
	SHORT	Sandoptal.................	N.N.R.	allyl	isobutyl		
	SHORT	Pernoston.................	N.N.R.	bromallyl	Betabutyl		
	SHORT	Pentobarbital (Nembutal)...	N.N.R.	ethyl	1-methylbutyl		
	SHORT	Phanodorn................	N.N.R.	ethyl	cyclohexenyl		
Decrease	SHORT	Ortal-sodium..............	N.N.R.	ethyl	n-hexyl		
	ULTRA SHORT	Evipal....................		methyl	cyclohexenyl	methyl	
	ULTRA SHORT	Pentothal sodium..........	N.N.R.	ethyl	1-methylbutyl		thio

Individual Differences

1. Phenobarbital causes depression of the motor cortex and occasionally a dermatitis.
2. Barbital inhibits cardiac irregularities caused by ephedrine.
3. Certain N-alkyl derivatives occasionally produce clonic stimulation.

Group Differences

1. The latent period, or interval between administration and sedative effect, is shorter with the shorter-acting drugs.
2. The sedative effect obtained from the same doses given orally to different patients is apt to be more uniform with the long-acting drugs.
3. The ratio of intravenous to oral doses is greatest with the drugs of shortest action. Therefore doses for intravenous use cannot be determined from accepted oral doses.
4. Elimination
   (*a*) Eighty per cent of barbital and 30 per cent of phenobarbital are eliminated in the urine.
   (*b*) Others are almost entirely destroyed in the body.
   (*c*) With massive doses, most barbiturates will "spill over" into the urine.
5. Contraindications
   (*a*) Short-acting barbiturates are probably contraindicated in the presence of poor liver function.
   (*b*) Long-acting barbiturates are probably contraindicated in the presence of poor kidney function.

Action

Type: Barbituric acid derivatives are sedative and hypnotic (not analgesic). They are anesthetic only in large doses (50 to 70 per cent of the lethal dose).

Degree: The degree of sedation for any one barbiturate, as for any depressant, is dependent on the dose.

Duration: From the standpoint of the clinician, barbiturates are best classified on the basis of duration of action (long, intermediate, short and ultrashort).

When a fixed percentage of the minimal lethal dose is administered intravenously, the compounds show differences in duration of action, as indicated in the legend to figure 20.

With oral administration, it is frequently impossible to differentiate clinically between the lengths of action of barbiturates occurring near together in the list. Thus a physician really requires not more than one barbiturate from each of the four groups.

The duration of action depends to a certain extent on the dose; thus the short-acting barbiturates when taken orally in massive doses have comparatively long action.

Administration

Oral

Form: Either the acid (relatively insoluble) or the sodium salt of the acid (water soluble).
Drugs: Primarily those of short, intermediate and long action. (Present indications are that those of ultrashort action are not suitable for oral administration.)

Intravenous

Form: Sodium salt, in 1 to 5 per cent solution.
Drugs: Primarily those of short and ultrashort action.
Use: For emergency use only.

Clinical Indications

Anesthesia: Use a barbiturate only if the administrator is experienced in the use of these drugs. Use only the ultrashort-acting barbiturates.

Convulsions (as from strychnine, etc.): Give a short-acting barbiturate by vein in a dose sufficient to control the convulsions.

Eclampsia: Use a barbiturate of short or intermediate action.

Epilepsy: Use the long-acting drug phenobarbital.

Ordinary Nervous Insomnia: Use those of short or intermediate action.

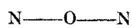
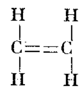
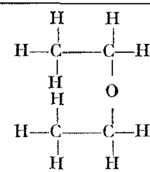
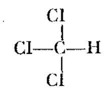
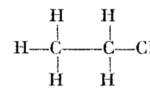
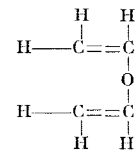
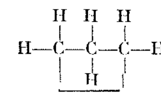
Preanesthetic Depression: Use a short-acting barbiturate (an intermediate or long-acting barbiturate may be given the night before).

Prophylaxis Against Toxic Effects of Cocaine or Infiltration Anesthetics: Give a barbiturate of short or intermediate action on an empty stomach about one hour before the administration of the local anesthetic.

Treatment for Overdose

1. Wash out stomach.
2. Give artificial respiration. Make sure the airway is clear. Aspirate mucus from the respiratory tract if necessary.
3. Give oxygen and stimulants—picrotoxin or metrazol, to be given symptomatically.
4. Maintain normal body temperature.
5. Change patient's position frequently.
6. Combat cerebral and pulmonary edema and acidosis when necessary.

TABLE 5.—*Physical and Pharmacologic Properties of Inhalation Anesthetic Agents*

Trade name	Nitrous oxide U.S.P.	Ethylene U.S.P.	Ether U.S.P.	Chloroform U.S.P.	Ethyl chloride U.S.P.	Vinethene N.N.R.	Cyclopropane
Chemical name	Nitrous oxide	Ethylene	Di-ethyl ether	Trichlormethane	Ethyl chloride	Divinyl ether	Trimethylene
Structural formula							
Boiling point	Gas, —89.4 C.	Gas, —102.7 C.	34.6 C.	61 C.	12.2 C.	28 C.	Gas, —34.6 C.
Specific gravity (Air)	1.52	0.97	2.56	4.10	2.23	2.42	1.45
Stability	Stable in steel cylinders	Stable in steel cylinders	Relatively stable Satisfactory	Stable in colored bottles. Satisfactory	Stable in container	Unstable after opening	Stable in metal containers
Inflammability and explosibility	Noninflammable, supports combustion	INFLAMMABLE EXPLOSIVE	INFLAMMABLE EXPLOSIVE	Noninflammable	INFLAMMABLE EXPLOSIVE	INFLAMMABLE EXPLOSIVE	INFLAMMABLE EXPLOSIVE
Pleasantness of induction	Pleasant	Unpleasant odor	Irritating, unpleasant	Mildly unpleasant	Mildly unpleasant	Mildly unpleasant	Pleasant
Muscular relaxation with adequate oxygen	None, limited to plane 1 of stage III	Poor, limited to planes 1 and 2	Excellent	Excellent	Fair	Good	Good

Mucous secretions	Minimal	Minimal	Marked increase in induction and light anesthesia	Increased during induction	Increased during induction	Marked increase in induction and light anesthesia	Moderate increase during induction and light anesthesia
Local effect on the respiratory tract	None	None	Irritation	Moderate irritation	Moderate irritation	Moderate irritation	Minimal with anesthetic mixtures
Effect on respiration	Slight stimulation, no depression with adequate oxygen	Same as nitrous oxide	Stimulation early; depression with deep anesthesia	Same as ether	Same as ether	Same as ether	No stimulation; depression increases with depth of anesthesia
Respiratory arrest	Caused by acute oxygen want. Imminent danger to heart and brain	Same as nitrous oxide	Due to deep anesthesia. Danger increased if oxygen want is permitted	Due to deep anesthesia. Danger of cardiac toxicity and oxygen want	Same as chloroform	Due to deep anesthesia. Cardiac toxicity undetermined. Danger increased by oxygen want	Due to deep anesthesia. Danger of cardiac toxicity and oxygen want
Cardiac arrest	Caused by acute oxygen want	Caused by acute oxygen want	Rare in the absence of oxygen want	Usually from overdose. Light anesthesia believed to favor ventricular fibrillation	Same as chloroform	Cardiac toxicity undetermined	May be caused by sudden overdose, otherwise does not precede respiratory arrest
Effect on cardiac rhythm	Minimal. Arrhythmia with oxygen want	Same as nitrous oxide	Occasional arrhythmia, not of serious nature	Arrhythmia common	Similar to chloroform	Undetermined	Bradycardia. Sudden tachycardia or arrhythmia with high concentrations
Liver damage	None without oxygen want	None without oxygen want	Minimal with proper oxygenation	Some degree common. May be severe with oxygen want or preexisting damage	Undetermined	Minimal with adequate oxygen and short duration	None with adequate oxygen
Rate of recovery	Rapid	Rapid	Slow after the body tissues are saturated	More rapid than ether	Rapid	Rapid	Variable. Usually rapid even after tissue saturation

TABLE 6.—*Drugs for Topical, Regional and Spinal Anesthesia*

Drug	Ratio of Effectiveness*	Topical Anesthesia	Regional Anesthesia	Spinal Anesthesia: Maximum Concentration Used	Spinal Anesthesia: Solution	Spinal Anesthesia: Specific Gravity Compared with Spinal Fluid	Spinal Anesthesia: Average Dose
Procaine hydrochloride	1.0	No value	0.50%—300 cc. 0.75%—150 cc. 1.0% —100 cc. 1.5% — 75 cc. 2.0% — 50 cc.	5%	Cerebrospinal fluid	Heavier	50-200 mg.
Cocaine hydrochloride	5.0	1 to 10%		Not recommended			
Metycaine	1.25	5% paste	0.5% —350 cc. 1.0% —200 cc.	5%	Cerebrospinal fluid	Heavier	50-200 mg.
Pontocaine hydrochloride	10.0	1 to 2%	Not recommended	1%	Cerebrospinal fluid-dextrose	Varies with spinal fluid	8-18 mg.
Nupercaine	7.0	1% paste	Not recommended	0.075% (1:1500)	1:1500 commercially prepared	Lighter	10-18 cc.
Butyn sulfate	4.0	1 to 2% 1% paste	Not recommended	Not recommended			
Diothane hydrochloride	.025	1% solution 1% paste	Not recommended	Not recommended			

* Comparative toxicity cannot be stated accurately since it depends on: (1) quantity of drug; (2) strength of solution; (3) rapidity of application; (4) rate of absorption (vascularity, vasoconstriction, etc.).

TABLE 7.—*Adjuvants Used by Anesthetists*

Drug	Route	Dose	Effects on*: Cortex	Medulla	Symphathetic	Parasympathetic	Ventilation	Pulse Rate	Blood Pressure	Gastrointestinal Tract	Detoxification	Method of Elimination	Signs of Toxicity
Alcohol	Injection	2-10 cc.	—	—	0	0	0	0	0	Secretions increased	Liver	Oxidation	Fibrosis or sloughing
	Oral	14.5 to 29.5 cc.	—	—	0	0	—	—	—	Secretions increased	Liver	Oxidation	Drunkeness, cyanosis, death from respiratory failure
Atropine	Subcutaneous	0.26-0.86 mg.	+	+	0	—	+	—	0	Secretions and motility reduced	Liver	Hydrolysis	Dry, flushed skin, fever, pupillary disturbance, tachycardia, ataxia, hallucinations
Avertin with amylene hydrate	Rectal	50-100 mg. per Kg. †	—	—	—	0	—	+	—	Motility reduced	Liver	Conjugation	Respiratory depression
Bromide	Oral	0.97-1.94 Gm.	—	—	0	0	0	0	0	0	Excreted unchanged	Excretion in urine	Dermatitis, lacrimation, gastrointestinal upsets, mental effects
Carbon dioxide	Inhalation		0	+	+	0	+	—	+	0	0	Exhalation	Increase in minute volume, loss of consciousness, clonic convulsions, respiratory failure
Chloral hydrate	Oral	0.97-1.94 Gm.	—	0	0	+	0	0	0	Irritative effect	Liver	Conjugation	Stupor, drop in blood pressure, vasodilatation, cyanosis, fall in temperature
Metrazol	Subcutaneous	0.1-0.3 Gm.	+	+	0	0	+	0	0	0	Liver	Conjugation	Tonic and clonic convulsions, anoxemia, respiratory paralysis
Picrotoxin	Intravenous	5-20 mg.	+	+	+	0	+	—	+	0	Unknown	Unknown	Confusion, convulsions
Paraldehyde	Oral	3.8-17.5 Gm.	—	0	0	0	0	0	0	Irritative effect	Liver	Destroyed	Same as chloral hydrate
Scopolamine	Subcutaneous	0.13-0.65 mg.	—	—	0	—	+	0	0	Secretions motility reduced	Liver	Hydrolysis	Same as atropine

* In this column + signifies stimulation; —, depression, and 0, no effect.
† Dose in milligrams of tribromethanol (avertin).

TABLE 8.—*Sympathomimetic Drugs Used in Combination with Anesthetic Agents*

Drug Solution	Topical Anesthesia	Block Anesthesia	Spinal Anesthesia	Toxic Effects
Epinephrine hydrochloride 1:1000	Maximum, 1 cc.	0.1-1 mg. to 100 cc. of 1% sol. of procaine hydrochloride or metycaine		Vertigo, palpitation, headache, tachycardia, drop in blood pressure
Ephedrine hydrochloride or sulfate 50 mg. per cc.	Not recommended	Not recommended	15-75 mg. intramuscularly for all agents	Same as epinephrine
Neo-Synephrin hydrochloride 100 mg. per cc.	3-5 mg. to 100 cc. of 1% sol. of procaine hydrochloride or metycaine	3-5 mg. to 100 cc. of 1% sol. of procaine hydrochloride or metycaine	3-5 mg. intramuscularly for all agents	Slightly less toxic than epinephrine or ephedrine

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3. Hirschfelder, A. D., and Bieter, R. N.: Local Anesthetics, Physiol. Rev. **12**:190-282 (April) 1932.

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PHYSICAL SIGNS ACCOMPANYING INCREASING ACTION OF ANESTHETIC DRUGS

The physical signs accompanying varying degrees of narcosis are made unreliable and often masked completely by disturbances of respiratory function. A deficiency of oxygen or an excess of carbon dioxide in the central nervous system may be manifested in signs similar to, although independent of, those from drug effect. *The air passages must be free and unobstructed, and respiratory exchange must be adequate.*

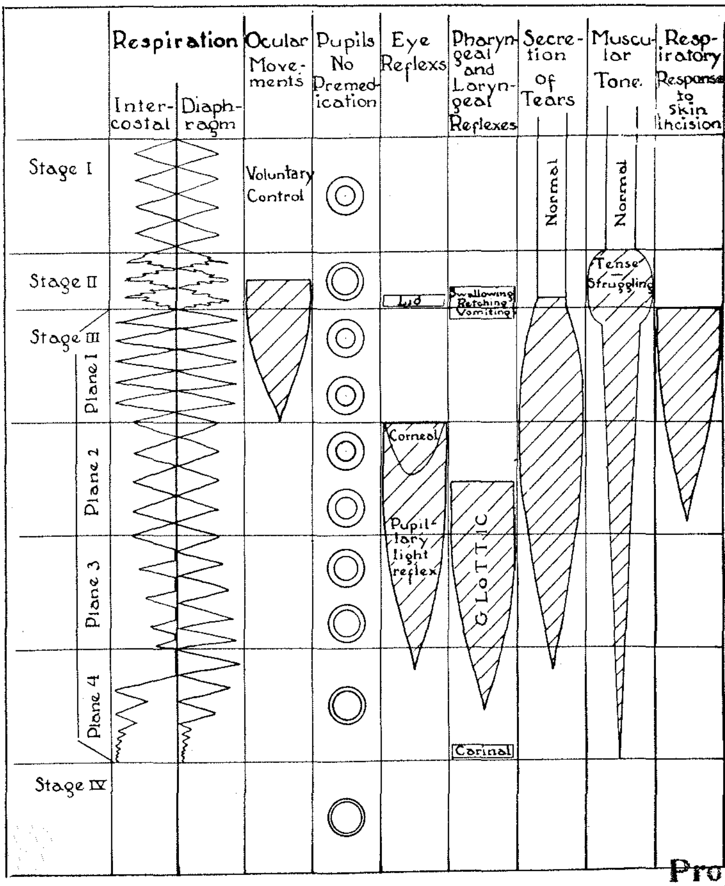

Fig. 21.—Diagrammatic representation of the chief signs of anesthesia. All the details shown are subject to considerable variation, and opinions vary with regard to them. They should all be taken into consideration in determining the level of anesthesia. The reader is invited to modify this chart in the light of his own observation.

STAGES OF ANESTHESIA

Stage I (Analgesia)

This stage extends from the beginning of the administration of the anesthetic to the loss of consciousness.

The patient is conscious and cooperative, but there is progressive loss of pain sensation. In this stage, minor surgical operations or the second stage of parturition may be accomplished; the patient will be aware of what is happening but if warned usually tolerates procedures that would be distinctly painful without analgesia. Unfortunately, there is no objective sign indicative of the transition to stage II, in which these stimuli may cause the patient to react violently.

Stage II (Delirium—Breath Holding—Struggling)

This stage extends from the loss of consciousness to the onset of regular automatic breathing.

No patient should be stimulated in any way during this stage. The higher cortical centers are paralyzed; sensations are misinterpreted; excitement may occur even without external stimuli, especially if the patient has been apprehensive. Some sensations persist after others have ceased. Hearing, the last to be abolished, may be exaggerated and distorted. A nightmare may lead to violent reactions. During this stage, respiration may be irregular in any way, and the pupil is often dilated but reacts to light. Vomiting may occur.

Stage III (Surgical Anesthesia)

The entry into the third stage is characterized by the onset of regular automatic breathing.

For more accurate estimation of depth, this stage is subdivided into four parts. Muscular relaxation increases as anesthesia deepens.

Plane 1

This plane is entered *when the eyelid reflex is abolished.* Respiration again becomes regular. The eyeball usually oscillates but may become eccentrically stationary. The swallowing reflex is abolished in this plane.

Plane 2

This plane is entered *when the eyeball movement is abolished and the eyeballs become concentric.* Respiration is still regular and deep. Under ether anesthesia the pupils may begin to dilate.

Plane 3

This plane is entered *when the intercostal activity begins to decrease or is delayed* (intercostal contribution to inspiration begins after diaphragmatic). Depth of respiration is reduced. Pupillary dilatation increases.

Plane 4

This plane is entered *when intercostal activity is completely paralyzed.* With progressive decrease in diaphragmatic activity, respiratory exchange is greatly reduced. Passive retraction of the chest on inspiration may occur, giving a false impression of intercostal activity unless the time relationship is carefully observed. Prolonged depression in this plane may lead to circulatory collapse. With some anesthetic agents the pupils are widely dilated.

STAGE IV (RESPIRATORY ARREST)

This stage is entered when the diaphragm is paralyzed. This condition should be treated by artificial respiration and elimination of the anesthetic agent.

During recovery the patient goes through the same planes and stages in the reverse order.

As is true of other clinical signs, the signs of anesthesia are not infallible. Individual variations may occur, and in estimating the depth of anesthesia the anesthetist should consider the whole picture as it is presented to him. For example, in a few cases it has been observed that eyeball movement has persisted until very deep anesthesia was produced.

Although the points at which the various reflexes disappear vary in different persons, as signs of the plane of anesthesia in a particular patient they are valuable and trustworthy. It must be remembered, however, that there is a time element involved in the accomplishment of tissue saturation. Do not expect all physical signs to develop with equal rapidity during induction.

WAIT FOR THE SIGNS TO CATCH UP WITH THE AGENT.

It is the primary duty of an anesthetist to insure the patient's safety while providing the surgeon with the best possible conditions for operation. The necessary depth of anesthesia varies with the individual patient, the surgeon and the particular operation. The ideal is to obtain perfect conditions with the lightest possible anesthesia.

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NOTES

IV
Relief of Pain

THE RELIEF OF PAIN is one of the chief functions of a physician and certainly of an anesthetist.

Considerations:

1. Medication with depressant drugs is not the only method of relieving pain. The proper type of bed and a comfortable position supported by pillows may provide as much relief as a quarter grain of morphine.

2. Freedom from worry and apprehension will go a long way toward bringing comfort.

3. The dose of a pain-relieving drug is "enough," but only within the realm of safety. This attitude can be assumed only if the physician is willing to assume responsibility for proper protection of patients so medicated.

4. Some factors influencing the choice and dosage of pain-relieving drugs are: (*a*) Age: During a normal life span the metabolic activity varies according to the body functions predominating at that period. At birth the metabolic activity is relatively low; it then gradually increases so that it reaches a peak at about 6 to 8 years. There is a slight decrease thereafter until about the age of 10, when puberty begins to exert an influence, and a new peak is reached at 12 to 15 years. Following puberty there is a moderate decline of metabolic activity to about 20 years. From this age the decline is gradual until old age. This means that, the factors indicated in table 9 being normal, the very young and the old will require smaller doses of depressant drugs, whereas those in the more active period of life will tolerate correspondingly larger doses. (*b*) Those in the center column of table 9. Any patient in whom the factors listed at the left in table 9 pre-

dominate will tolerate a larger dose of depressant medication, while one in whom the factors at the right predominate will require a correspondingly smaller dose.

TABLE 9.—*Factors Influencing Patients' Tolerance of Pain-Relieving Depressant Drugs*

Hypersthenia Healthy Strong Active	Strength	Hyposthenia Debilitating illness Burns Chronic infections
Acute fever	Temperature	Hypopyrexia—long exhaustive fever
Fear Anger Irritability Worry	Emotional state	Pleasant disposition Cooperative attitude Lethargic behavior
Pain Uncomfortable feeling from impure air Hunger Full bladder	Bodily comfort	"Bliss" (bodily state just before rising) Ideal nursing care Perfect hospital environment
Hyperthyroidism	Endocrine activity	Hypothyroidism

If complete comfort is secured for all patients, some in whom extreme depression has occurred will be encountered. The anesthetist must recognize this fact and be on guard. Depression from drug action is a frequent cause of death, yet death rarely need occur from such a cause if adequate respiratory exchange is maintained with airways (p. 25) and artificial respiration (p. 153).

GENERAL ANESTHESIA

General anesthesia involves supplying to the brain by way of the blood stream a narcotizing agent in sufficient concentration to produce loss of consciousness. The agent may be introduced into the blood stream by one of the following routes:

1. Mouth (Oral Administration).
2. Skin (Subcutaneous Administration).
3. Rectum (Rectal Instillation).
4. Vein (Intravenous Instillation).
5. Respiratory tract (Inhalation Method).

Before the patient is anesthetized, the following conditions should be provided:

1. The identity of the patient and the nature and the site of the proposed operation should be established.
2. Written permission to perform the operation must have been signed by the patient or by his legal representative. (This may not apply under military conditions.)
3. A third person, preferably of the same sex as the patient, should be in the room and remain in attendance.
4. Avoid psychic trauma by preliminary medication.
5. Administer scopolamine hydrobromide or atropine sulfate to minimize secretions.
6. The patient should be made as comfortable as possible on the operating table. For example, if he is in the supine position, he should have a large pillow under his head, another under his knees, and possibly one under the lumbar curve. Care should be taken to have the extremities supported so that there will be no undue local pressures with possible sequelae.
7. There should be no foreign body in the mouth which might cause obstruction.
8. There should be no unnecessary mechanical interference with respiration (loose clothing and dressings).

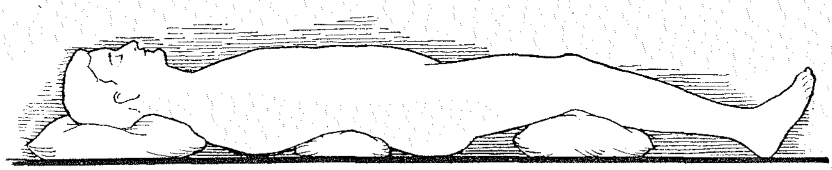


Fig. 22.—The patient is made as comfortable as possible before anesthetization.

ORAL ADMINISTRATION

Such drugs as alcohol, paraldehyde, the barbiturates and the opiates when introduced into the gastrointestinal tract and absorbed by the blood may produce a sufficiently profound state of analgesia to allow minor surgical intervention. Anesthesia of this type does not provide profound relaxation.

Some degree of respiratory depression may accompany such narcosis. The recovery period may be long.

Individualization of dosage and specialized attention, particularly to respiration, are required.

For example, in 1918 Gwathmey and Karsner recommended:

℞	Peppermint water	5 minims (0.3 cc.)
	Ether	4 fluid drachms (14.5 cc.)
	Liquid petrolatum	4 fluid ounces (118 cc.)

This mixture was administered by mouth fifteen to twenty minutes before painful dressings, as a "sandwich" between sips of port wine.

Marshall modified the formula as follows:

℞	Ether	1½ ounces (44 cc.)
	Chloroform	20 minims (1.2 cc.)
	Liquid petrolatum sufficient to make	4 ounces (118 cc.)

This mixture was used as the first one was. Recovery was reported as prompt, without nausea.

Other formulas and other drugs deserve trial in oral administration.

For drugs and their effects, see pp. 31 to 50.

For management of respiration, see pp. 25 and 152.

SUBCUTANEOUS ADMINISTRATION

The subcutaneous administration of anesthetic drugs requires specialized attention because of the need for individualization of the dosage over a period of time, careful choice of agents and supervision of respiratory depression.

For example, anesthesia has been accomplished by repeated hypodermic injections of a solution of morphine sulfate and scopolamine hydrobromide. One-fourth grain (0.015 Gm.) to three-fourths grain (0.045 Gm.) of morphine sulfate combined with one twenty-fifth as much scopolamine hydrobromide is a usual initial dose. After one hour the patient is observed as to (1) general depression, (2) size of pupils, (3) change in cardiac or in respiratory rate and other effects. A second injection is then made, the two drugs being usually in the same proportion. The amounts of the second and successive doses should be based on the progress of the general depression toward loss of consciousness. The rate of respiration and the size of the pupils are the guides. If the respiratory rate is slow and the pupil the size of a pinpoint, later doses should contain more scopolamine at the expense of morphine. If the respiratory rate is fast and the pupil large, less scopolamine should be used, or this drug should be omitted, in later doses. With two to four or five injections over a period of two and a half hours, a condition permitting major surgical procedures may be produced.

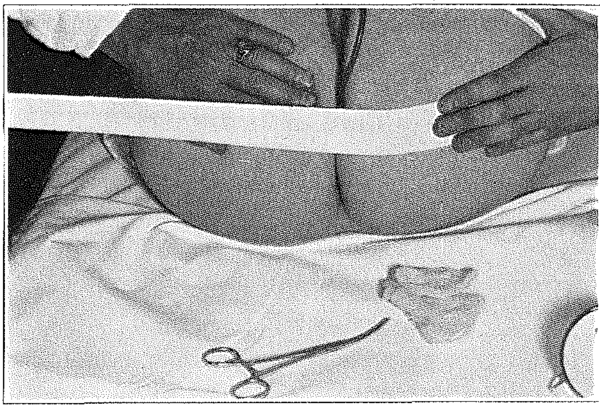
Pharyngeal airways (pp. 12, 25 and 26) are necessary, and oxygen-enriched atmosphere is desirable.

Overdosage of nonvolatile sedative or narcotic agents need never be fatal if adequate respiratory function is maintained. On the other hand, patients who are neglected after such medication occasionally present complications or die.

NOTES

RECTAL INSTILLATION

A



B

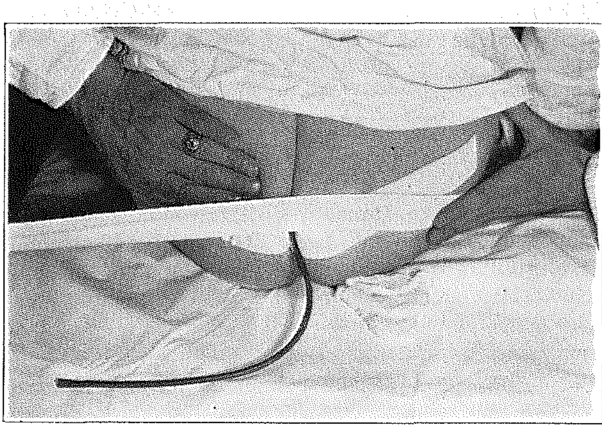


Fig. 23.—In *A* a urethral catheter is inserted beyond the anal sphincter. A strip of adhesive tape at least 18 inches (45.5 cm.) long is firmly attached and held to the skin of one buttock and pulled across to the opposite side, passing *below* the protruding catheter. It is secured only after forcing the buttocks together.

In *B* a second strip is attached to one buttock, crossing the first and passing *above* the catheter in the midline, again crossing the first while pressure is applied to the other buttock. The second strip always gains better approximation of the buttocks in the midline than a single one.

The catheter may be inserted with the patient in Sims' position instead of on his back as shown here.

This method is applicable to the administration of certain anesthetic agents. In addition, it may be used for the administration of supportive fluids during or following operation.

By means of an attached funnel or a large syringe, the indicated amount of fluid, at body temperature, is instilled at once. The catheter may then be removed or clamped in place for a later instillation, but the adhesive strips should continue to hold the buttocks in close apposition until the fluid is absorbed. Quantities of fluid up to 1 quart (945 cc.) are thus retained without evacuation.

Anesthesia induced by rectal instillation requires (*a*) constant nursing care until the patient is conscious, (*b*) maintenance of a free airway and (*c*) oxygen therapy until respiratory depression has disappeared.

AGENTS

A few of the most commonly used rectal anesthetic agents and technics are listed here:

Ether in Oil

Agent.—A 65 per cent solution of ether in olive oil (cottonseed oil, neat's foot oil or Russian liquid petrolatum may also be used). A newer preparation which has been suggested is colloidal lathesia, which is a solution of ether in a purified coagulum of the latex tree. One ounce (29.5 cc.) of lathesia consists of 1 fluid ounce of ether plus 40 grains (2.5 Gm.) of coagulum.

Dose.—The dose of the 65 per cent solution of ether in oil is 1 ounce per 20 pounds (29.5 cc. per 9 Kg.) of body weight, but the total dose is never to exceed 8 ounces (185 cc.) of solution regardless of the weight of the patient. In children and in weak anemic adults, a 65 per cent or even a 50 per cent solution may be used.

The dose of lathesia for full anesthesia of the average adult is 5 ounces (155.5 Gm.). When lathesia is used for basal narcosis, the dose is 2 to 3 ounces (62 to 93 Gm.)

Duration.—If the maximum dose of ether in oil (65 per cent solution) is given, anesthesia should last for two and a half to three hours.

Preparation of Patient and Technic

1. Give warm water enemas in the morning at intervals of one hour until the return is clear.
2. Allow a two to three hour period of rest.
3. Apply a seaweed or tragacanth lubricating jelly about the anus.
4. Instill rectally 2 to 4 drachms (7.5 to 15.5 cc.) of paraldehyde in an equal amount of olive oil one hour before the operation.

5. Give a hypodermic injection of a solution of morphine sulfate (¼ to 1/12 grain [0.016-0.005 Gm.]) and atropine sulfate (1/100 to 1/200 grain [0.65-0.32 mg.]) one half hour before operation.
6. If the dose given rectally proves insufficient, it can be supplemented either by allowing the patient to rebreathe the ether excreted by his lungs or by administering additional ether by inhalation.
7. Administer oxygen through a pharyngeal airway or a face mask.
8. For overdosage, use carbon dioxide 5 per cent and oxygen 95 per cent to hyperventilate the patient and extract the ether by way of the lungs (no rebreathing).

Technic in Obstetrics

1. With onset of labor pains, give soluble pentobarbital (pentobarbital sodium), 3 grains (0.19 Gm.) by mouth.
2. When pains next become severe, give soluble pentobarbital (pentobarbital sodium), 1½ grains (0.09 Gm.), plus morphine sulfate, ¼ to 1/6 grain (0.016 to 0.010 Gm.), hypodermically.
3. Instill rectally:

   Ether....................2½ ounces (59 cc.)
   Paraldehyde...............2 drachms (7 cc.)
   Olive oil sufficient to make..4 ounces (118 cc.)

   Here one must use the same precaution of applying a protective jelly about the anus, and one must insert the catheter into the rectum 6 to 8 inches (15 to 20 cm.) to be sure that it is past the presenting part. On instillation, the patient should be told to breathe deeply through the mouth and to try to tense the muscles as if to keep from expelling gas.
4. Repeat instillation every two and a half hours for as long as is necessary.
5. During actual delivery, supplement the agents given by this procedure with nitrous oxide or with ether by inhalation.

PARALDEHYDE

Agent.—A 10 per cent solution of paraldehyde in oil or saline solution.

Dose.—Approximately 6.3 cc. of the 10 per cent solution per kilogram of body weight, the total dose never to exceed 320 cc., regardless of the weight of the patient.

Time.—The solution is to be instilled forty-five minutes before operation.

Avertin with Amylene Hydrate (100 per cent tribromethanol in amylene hydrate)

Agent.—A 3 per cent solution of avertin with amylene hydrate in distilled water warmed to 40 C. It must be freshly made for each case; it must be well shaken to be sure the tribromethanol is dissolved; it must not be allowed to cool much below 40 C. as the tribromethanol may crystallize out. It must be tested with congo red dye. If the solution has a tendency to turn blue, it should be discarded, as this indicates the presence of decomposition products that are irritating to the rectal mucosa (dibromacetaldehyde). (For dosage, see p. 45.)

Pentothal Sodium

Agent.—The powder is dissolved in 20 or 30 cc. of distilled water. (Evipal sodium [the sodium salt of N-methyl-C-C-cyclohexamylmethyl barbituric acid] is also given in the same dose and manner.)

Dose.—This is 0.1 Gm. per year of age, with a maximum dose of 2 Gm. (mainly used in children).

Time.—The patient is anesthetized in fifteen minutes, and the effect lasts about thirty minutes.

Supportive Agents

Supportive liquids that can be given rectally include water, physiologic solution of sodium chloride, dextrose in saline solution or in water (usually a 5 per cent solution), Ringer's solution, Hartmann's solution, Bourne's solution, alcohol in the form of wine, etc. Alcohol is usually given as port wine—100 to 300 cc. before, and 500 cc. after, operation.

Bourne's stock solution is: 100 Gm. of potassium bicarbonate plus 358 Gm. of disodium phosphate crystals in 2 liters of distilled water. An ounce of the stock solution is added to a pint of distilled water for every 50 pounds (22.5 Kg.) of body weight—not more than a quart being given at one time.

References

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INTRAVENOUS INSTILLATION

Barbiturates may be injected intravenously to produce sleep and a state resembling anesthesia. Pentothal sodium will be used here as an example. Ultrashort-acting drugs are usually preferable for intravenous use (p. 38).

Two persons are required to conduct intravenous anesthesia properly—an anesthetist and an assistant. The duties of each are

Assistant:

1. Prepares and injects sterile solution.
2. Avoids extravascular injection.
3. Administers drug symptomatically, slowly or intermittently.
4. Uses dilute solutions to avoid toxic effects and tissue irritation.

Anesthetist:

1. Carefully observes rate and depth of respiration, pulse rate and blood pressure.
2. Maintains a free airway.
3. Treats any immediate toxic effects.
4. Administers oxygen.
5. Inserts airway if indicated (p. 25).
6. Administers artificial respiration if indicated (p. 153).

Intravenous anesthesia should never be employed unless the anesthetist is prepared and equipped to perform efficient artificial respiration.

Equipment

A medium-sized syringe with small graduations and venipuncture needles of the usual size are necessary equipment.

Caution: It must be remembered that intravenous anesthesia is a form of general anesthesia. Complications which may accompany other forms of general anesthesia can occur with intravenous anesthesia, so one must be prepared to meet them. The most dangerous of these are respiratory obstruction and respiratory depression with the accompanying oxygen want; therefore one must be prepared to administer oxygen under pressure (p. 193) and to insert an artificial airway (p. 25).

Preparation of the Solution

A 2.5 per cent solution of the barbiturate is less dangerous. This is prepared by dissolving a 1 Gm. ampule of the agent in 40 cc. of sterile distilled water.

1. Use surgically aseptic technic in preparing the solution.
2. Be sure the powder is thoroughly dissolved. Discard a cloudy solution or one containing a precipitate or other foreign material.
3. Use a fresh solution. When light and air are excluded, the solution will remain stable for several hours.

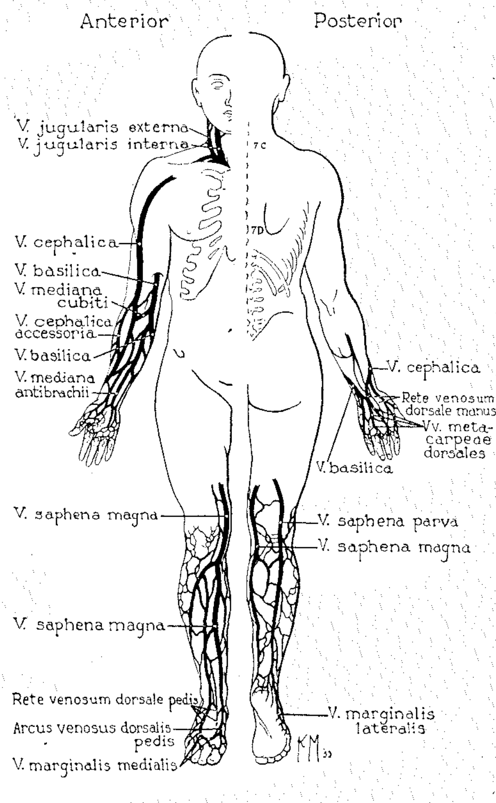

Fig. 24.—A schematic representation of the superficial veins of the body which are available for venipuncture.

Preliminary Medication

The amount of preliminary medication will vary with the age and general condition of the patient (pp. 31-50). For some it will have to be increased, and for others, decreased. Usually it is advisable, though not necessary, to give morphine and scopolamine one and one-half hours before operation.

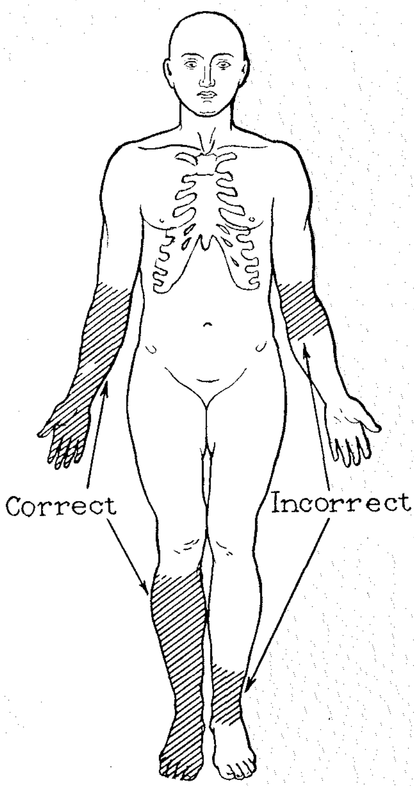

Fig. 25.—In order to make the veins more prominent and easy to identify apply hot wet towels surrounded by waterproof fabric for one half hour. The diagram shows correct and incorrect sites of application.

Steps Involved in Intravenous Instillation

A skin wheal is raised over the vein with a 0.5 per cent solution of procaine hydrochloride.

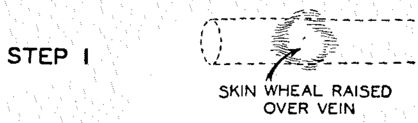

Fig. 26

After shifting this wheal the needle is thrust into the tissue at the side of the vein.

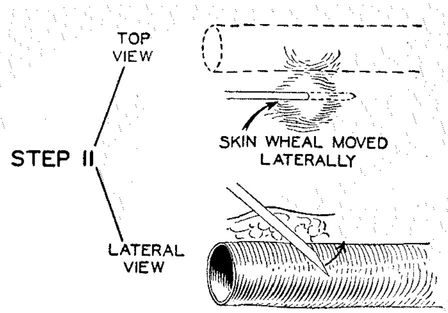

Fig. 27

The needle point and wheal are then returned to a position directly over the vein and the puncture made. The illustration shows the importance of holding the bevel parallel to the wall of the vein to avoid having the bevel lie partially in and partially outside the lumen of a small or collapsed vein.

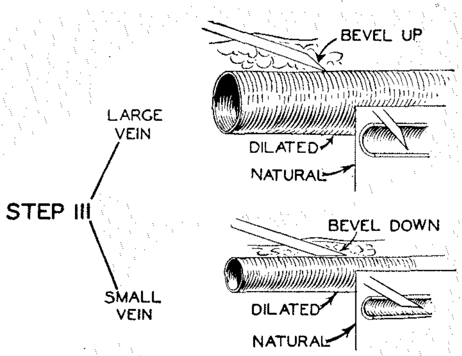

Fig. 28

AN INTRAVENOUS NEEDLE, WITH STYLET, PLACED IN A VEIN BEFORE OPERATION DOES NO HARM. WHEN THE NEED ARISES, REMOVE THE STYLET AND CONNECT THE RUBBER TUBING.

Induction of Anesthesia

1. Inject the solution slowly, carefully watching its effect on the patient. Stop when the depth of anesthesia is judged sufficient for that operation.
2. When anesthesia has been induced, a piece of cleansing tissue with adhesive may be placed over the patient's mouth and nostrils to act as an indicator of the respiratory activity.
3. It is advised that oxygen be administered during intravenous anesthesia.

Maintenance of Anesthesia

1. For maintenance, administer small fractional doses intermittently.
2. As anesthesia lightens (evidenced by increased depth of respiration, movement or straining), administer further solution.
3. During a long operation, reduce the size and frequency of the doses of pentothal sodium as the operation progresses.
4. As the operation nears completion, lighten the anesthesia as much as possible.

N. B.—Patients vary widely in their tolerance for barbiturates. Therefore effective doses will vary in different patients.

Signs and Effects of Anesthesia

The signs for other forms of anesthesia are true for this type except that the ocular and respiratory signs do not match reflex obtundation. Fourth plane respiration accompanies first plane reflex obtundation as a rule (see pp. 47-50).

Dangers

1. Respiratory arrest—due to (*a*) large doses or (*b*) rapid injection.
2. Respiratory depression resulting in inadequate exchange of oxygen and carbon dioxide.
3. Respiratory obstruction.

Precautions

1. Free airway.
2. Small fractional doses.
3. Slow rate of injection.

4. Administration of oxygen throughout the operation.
5. Avoidance of extravascular injection.
6. Supplementation by another method when satisfactory anesthesia cannot be safely accomplished or when large doses must be administered.
7. Avoidance of intra-arterial injection. It is dangerous.

NOTE.—Intravenous anesthesia may be used for certain major operations by combining it with spinal, regional or local anesthesia and administering oxygen or oxygen and nitrous oxide.

CONTRAINDICATIONS

1. Impaired liver function.
2. Cardiac disease with associated dyspnea or with anemia.
3. Diseases of the veins.
4. Any disease of the lungs resulting in marked decrease in alveolar surface.
5. Obstructing lesions of the gastrointestinal tract.
6. Operations about the upper respiratory passages associated with severe bleeding.
7. Respiratory obstruction.

Paraldehyde when properly prepared may be administered intravenously in doses of 5 to 10 cc. It produces anesthesia for several minutes and sleep for a variable period.

Morphine when given intravenously will produce comparable narcosis in slightly smaller doses and in less time than when given subcutaneously. For this reason it is valuable for quick premedication. Scopolamine or atropine may be combined with it in the usual ratio (see pp. 32-37).

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INHALATION METHODS

Inhalation is the method by which an anesthetic agent enters the body through the respiratory tract.

In the presence of anatomically and physiologically normal respiratory and circulatory systems the transport of anesthetic gases and vapors, of oxygen and of carbon dioxide will depend on the following factors:

1. Partial pressure of the anesthetic agent, oxygen or carbon dioxide. The higher the partial pressure, the greater the diffusion.
2. Efficiency of ventilation. The better the ventilation, the quicker the gas or vapor will get in or out.
3. Permeability of the diffusion surfaces. Since in a normal subject this does not change, it will allow free transport across the alveolar membranes. In diseased states it may be markedly altered.
4. Blood flow through lungs. This is usually constant. Many factors will influence the transport of gases in diseased states. These have been discussed on pages 9 to 18.

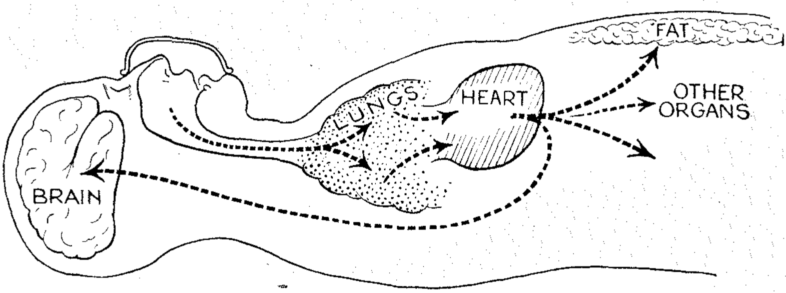

Fig. 29.—Routes taken by the anesthetic.

The anesthetic passes from the lungs to the blood stream, which transports it (1) to the brain, which becomes saturated quickly, and (2) to fats and other tissues, which become saturated slowly.

A high concentration is required in induction.

During maintenance the fats, etc., gradually become saturated, and consequently the rate of administration may gradually be decreased, without change in the depth of anesthesia.

Changes in surgical requirements call for varying depths of anesthesia. Such variations should be brought about smoothly without sudden changes in the concentration administered.

When administration ceases, the rate of recovery depends partly on the amount of anesthetic agent dissolved in the body tissues. Recovery from a short but deep anesthesia will be more rapid than from a long anesthesia in which greater saturation of tissue has occurred.

OPEN DROP ADMINISTRATION IS THE MOST WIDELY ABUSED OF ALL METHODS.

OPEN DROP ADMINISTRATION
(Applicable to all volatile agents)

"Open drop" administration of the volatile agents will probably remain popular because of its simplicity and controllability. It is an excellent method to use in teaching students the technic of obtaining general anesthesia, since it requires more precise technical management than other methods if perfect results are to be obtained.

The Dripper
(A simple type)

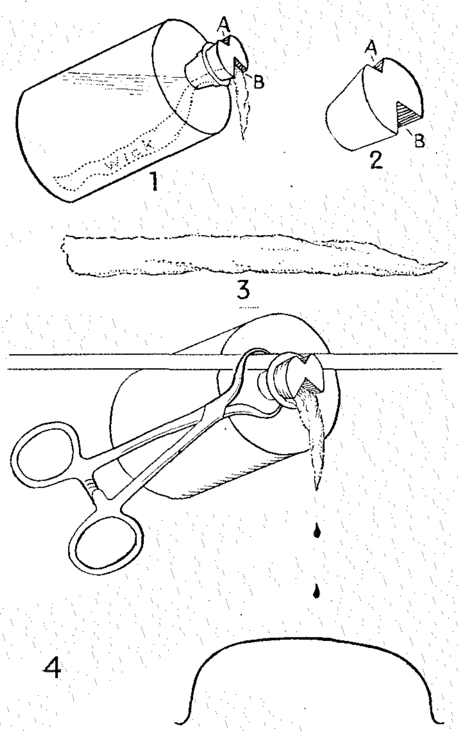

Fig. 30.—*1*, the container of the anesthetic liquid; *2*, the cork with two notches—one small (*A*) and one large (*B*); *3*, the wick—a strip of gauze or cotton long enough to reach to the bottom of the container, and coming to a fine point at the outer end; *4*, arrangement for convenience in maintaining a constant drip—the dripper may be fixed above the mask to a gooseneck support or to a screen by means of a bull's horn forceps.

The Drip

Smoothness of administration is the keynote of the drop methods. This is most important during induction. Skilfully managed, induction with open drop ether can be as pleasant to the patient as induction with a gas. Irregularity at the start, with sudden increases in concentration, can make it very unpleasant.

Almost any one can be taught to *pour* ether—only the really skilful administrator can give it well.

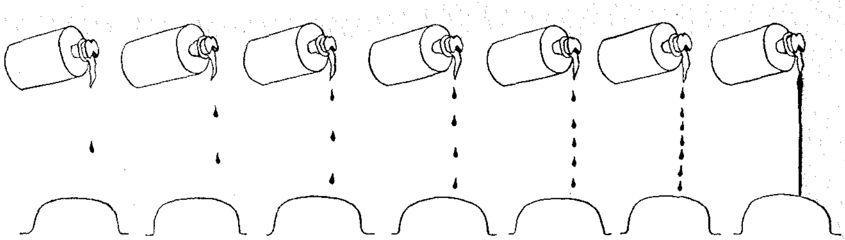

Fig. 31.—During induction the drip should be accelerated slowly, steadily and as rapidly as the patient will tolerate, never exceeding the amount that will vaporize on the mask. Throughout the administration the drip should be continuous—the rate varying as changes in depth of anesthesia are required.

The Mask

Since one purpose of the mask is to confine the agent in anesthetic concentrations at the nose and mouth, it should fit closely enough to prevent the vapors which are heavier than air from escaping around the edges.

The second purpose of the mask is to provide a site of vaporization. This is well enough served by 6 to 12 *single* layers of gauze. The use of more layers or of thicker fabrics is a definite hazard, because of the inevitable oxygen want and damming back of carbon dioxide.

The Vapor

Differences in potency and rapidity of action between different agents must be allowed for. Roughly, the order of amount needed during induction is as follows, with the

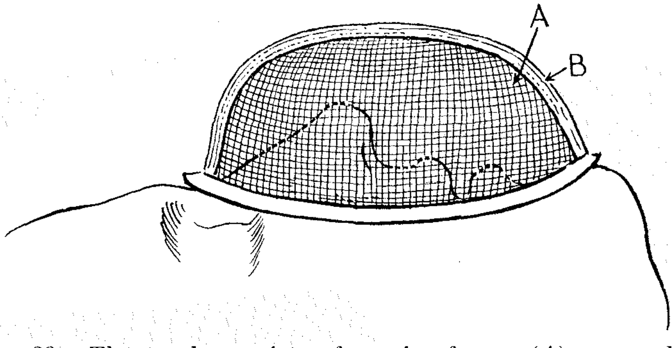

Fig. 32.—The mask consists of a wire frame (*A*) over which are fitted several layers of gauze (*B*). From 6 to 12 layers suffice—if too little, the agent drips through—if too much, respiration is obstructed. The mask should fit the face snugly so that (*a*) all air breathed in passes through the gauze and (*b*) vapor does not leak out around the mask. Therefore the mask should not be too large.

A towel or a cotton pad with a hole in its center may be used to (*a*) cover eyes and (*b*) improve fit of mask to face. A towel should not be misused to (*a*) build up dead space or (*b*) cover the mask and obstruct respiration.

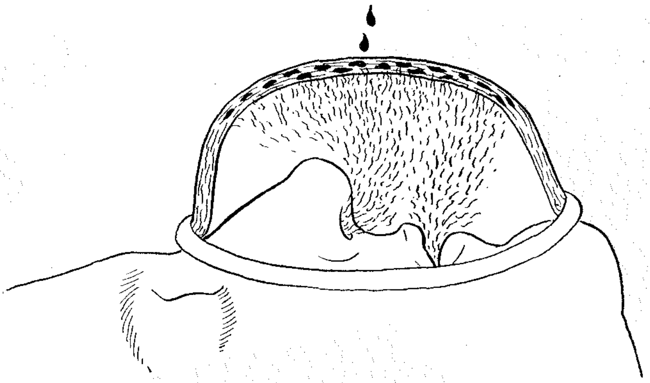

Fig. 33.—The vapor concentration depends on: (*a*) the temperature and the barometric pressure; (*b*) the rate of flow of air through the gauze, i. e., the minute volume of respiration; (*c*) the amount of agent on the gauze, and (*d*) the volatility of the agent. The vapor of all volatile agents is heavier than air and falls downward.

IT IS OPEN DROP TECHNIC ONLY AS LONG AS THE MASK IS TRULY OPEN.

greatest first: diethyl ether, ethyl chloride, divinyl ether, chloroform.

Weather may make a difference. On a damp day the patient's exhaled water vapor will quickly saturate the gauze and make vaporization of the agent too slow to be effective. In very hot dry weather such an agent as divinyl ether may vaporize and be dissipated about the room so rapidly that effective concentrations in the mask cannot be reached.

When respirations are depressed, as from drugs given before administration of the anesthetic, the shallow respirations may not carry in enough vapor to raise the alveolar concentration to effective levels. It is best to avoid full premedication before the administration of one of the volatile agents by the open drop technic.

The Rest of the Atmosphere

Though the method is called open, it is quite possible for oxygen lack or an excess of carbon dioxide to occur. If more than a minimum amount of gauze covering is used, or if towels or layers of gauze are wrapped about the mask, an open system no longer exists.

The mere addition of pure oxygen under the mask will not correct the carbon dioxide excess unless the oxygen flow is great enough to blow away the anesthetic vapor as well as the carbon dioxide.

The so-called ether convulsions occurring with the open technic have most often been seen when there was a definite possibility of oxygen lack and carbon dioxide excess, because of too much dead space and obstruction in large masks heavily covered with gauze and towels (see p. 174).

The Respiratory Mucosa

Though some volatile agents irritate the respiratory mucosa and so preclude overdosage during induction, others, like chloroform, do not irritate, and must be administered very cautiously.

All bring about local analgesia of the mucosa during induction; hence overdosage is eventually possible with all, without

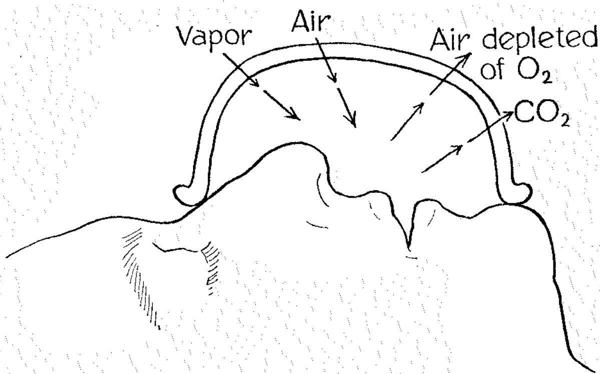

Fig. 34.—Air should gain free ingress, as it is the source of oxygen. Air loaded with carbon dioxide and depleted of oxygen comes from the lungs and should have free egress. Dead space (e. g., with too large a mask or a towel around the mask) causes: (*a*) increased carbon dioxide—usually a danger; (*b*) decreased oxygen—always a danger, and (*c*) increased concentration of the agent—sometimes an advantage.

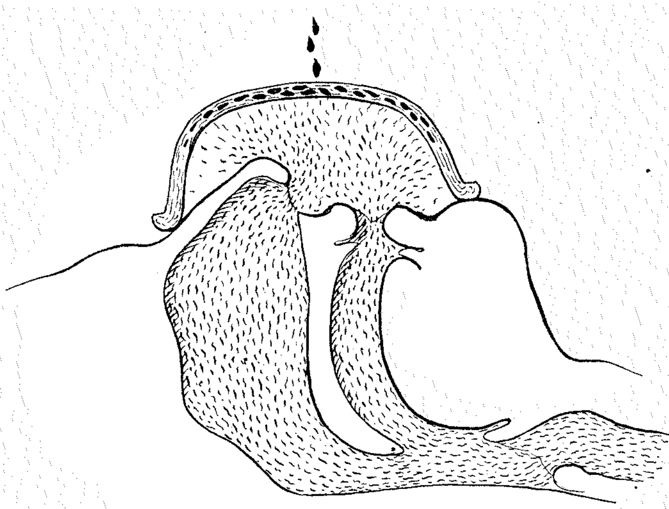

Fig. 35.—Anesthetic vapor causes: (*a*) Irritation with consequent resistance, excitement, hypersecretion and laryngospasm; (*b*) local analgesia counteracting these effects and causing tolerance. The increase in concentration should be so gradual that (*b*) precludes (*a*).

During induction: (*a*) Fit mask snugly to the patient's face. Then, with the mask in place, start the drip *very slowly*. (*b*) Patient should breathe naturally as when taking a nap (no deep breathing). (*c*) Increase drip gradually. Pause if the patient holds breath or objects.

warning resistance against irritants from the normal mucosal defenses.

Voluntary deep breathing during induction may lead to respiratory arrest when consciousness is lost, from the effects of the sudden heavy concentration of the agent and the blowing off of carbon dioxide.

★ ★ ★ ★ ★

Oral or Pharyngeal Insufflation

It is sometimes convenient to maintain anesthesia by insufflating anesthetic vapors or gases into the mouth or the pharynx in operations on the head or neck. The liquid agents can be vaporized by passing through them air or oxygen under pressure or by dropping the agents into the gases. Either the liquid or the gaseous agents can then be blown into the mouth or the pharynx through a metal hook in the side of the cheek or a rubber tube passed into the pharynx through a nostril. Such a method eliminates the need for a mask with the resultant increase in dead space. Obviously it is an expensive method of administration.

The necessary apparatus consists of an approved motor-driven pump, or a hand or a foot bellows, which can force air under pressure through a vaporizer containing a liquid agent and so deliver vapor to the patient. Similarly, compressed anesthetic gases and oxygen or compressed air may be released through or over the liquid agent to vaporize it. If a motor operates a positive pressure pump, it may also operate a negative pressure pump to provide suction for the aspiration of blood and other fluids from the field of operation. Motors on such apparatus must be of "explosion proof" construction and inspected and repaired frequently by an electrician so that ignition of ether vapor is impossible. Heating units have been included in such apparatus to promote more rapid vaporization of ether. These may be dangerous because of the possibility of igniting ether vapor as well as decomposing it into toxic by-products.

THE GAS MACHINE

In general, gaseous and volatile agents are most efficiently administered with some form of apparatus usually termed a gas machine.

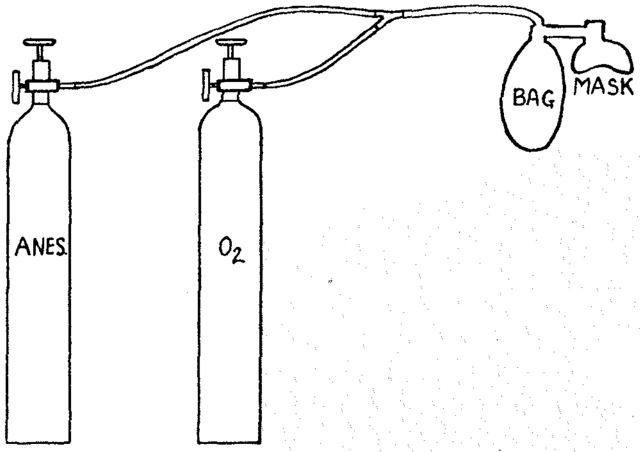

Fig. 36.—Simplest form of gas machine.

The common types of apparatus have the following characteristics:

1. Connections (or yokes) to which cylinders of compressed gases or tubes from a central supply can be attached in a leak-proof manner.
2. Fine control valves to regulate the flow of gases.
3. Meters to indicate the volume flow or the pressure of each gas.
4. Tubing to link valves and meters to a common mixing chamber and thence to the outflow tube.
5. A vaporizer to volatilize liquid agents as required.
6. Linked by tubing to the common outflow is some type of apparatus in direct connection with the patient's respiratory tract. This may take the form of a face mask, a nose mask, a mouth hook, a pharyngeal airway, or an endotracheal tube. Freely communicating with the mask, tube, etc., there is usually a breathing bag big enough to accommodate at least the maximum tidal volume of respiration.

COMPONENTS OF GAS MACHINES

Those familiar with any gas machine will doubtless recognize these oversimplified sketches of the various parts. The drawings may be of assistance in understanding the mechanics of the apparatus. Such knowledge is essential, so that the anesthetist is master of the machine and not at its mercy.

Automatic Flow Control

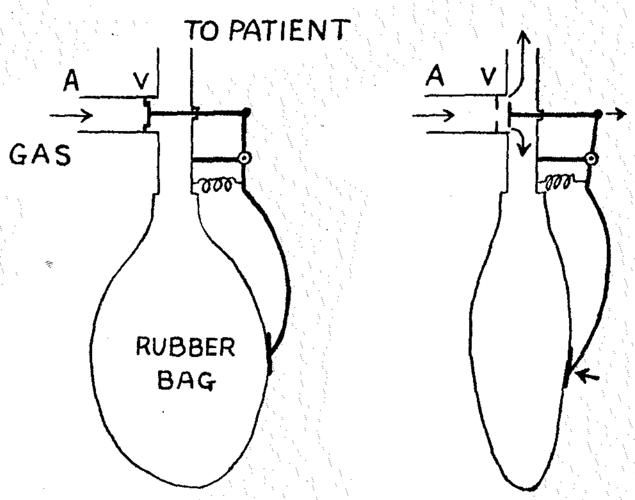

Fig. 37.—Intermittent flow control. Gas entering at *A* inflates the rubber bag, which causes valve *V* to close. Deflation of the bag by the patient's inspiration reopens the valve as shown, and allows the gas to flow again.

The rate of flow of a gas through a narrow orifice is dependent on its pressure. The flow meters shown in figure 38 indicate the rate of flow on a calibrated scale, by measuring this pressure.

At the left is the float type. Gas passing from *A* to *B* elevates the float in the tapered tube. Next is the Venturi type. As gas passes from *H* (high pressure) through orifice *O* to *L* (low pressure) water is depressed on the high pressure side. At the right, as gas passes from *H* through *O* to *L*, it increases pressure in the expansible drum *B*. By a system of levers connected to *C*, a needle moves on dial *D*.

Meters for Constant Flow of Gases

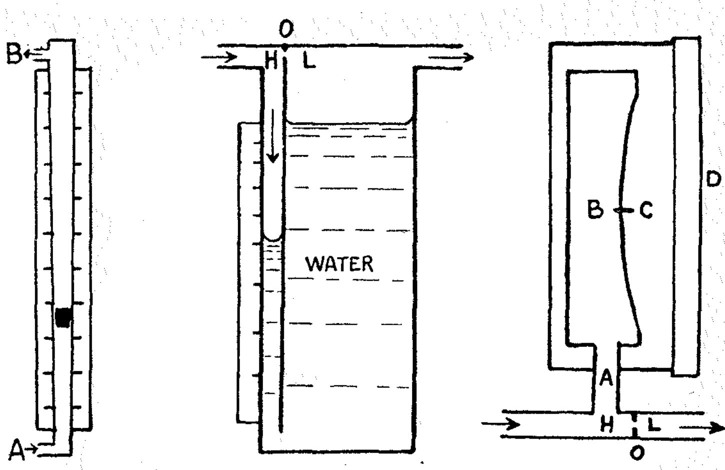

Fig. 38.—Types of meters.

Vaporizers

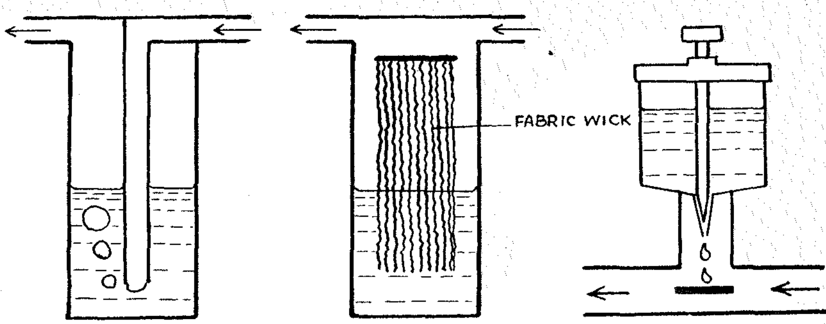

Fig. 39.—Types of vaporizers.

In figure 39, the vaporizer at the left shows a tube projecting into the volatile agent. By a shunt valve (not shown) gases may pass through or over the liquid, or may be by-passed completely. The middle sketch shows evaporation of the volatile agent enhanced by a wick. A shunt valve (not shown) passes the desired proportion of the gases through this chamber. At the right, note the visible, controllable drip of the volatile agent onto the plate in the course of the flowing gases.

ADMINISTRATION OF GASEOUS AND VOLATILIZED AGENTS

The principles of induction are the same in all inhalation anesthesia, whatever the drug and whatever the method.

The anesthetic agent gradually washes out and replaces the nitrogen from the apparatus, lungs, blood and other tissues.

For the weaker anesthetic agents (e. g., nitrous oxide and ethylene) the nitrogen must be thoroughly flushed out; otherwise it will interfere with anesthetization or oxygenation or both. This requires a rapid flow (5 liters or more per minute for five minutes), followed during the first hour by a slow flow and occasional emptying and refilling of the bag.

For the stronger agents the nitrogen need not be flushed out.

The drawings, with their explanatory legends, show the principles of induction and maintenance of anesthesia with gases and volatilized liquids, with and without the building up of abnormal levels of carbon dioxide in the patient's body.

Maintenance by Constant (or Intermittent) Flow and Escape

In *A* in figure 40 the flow of gas equals or exceeds the respiratory volume. All exhaled gas passes out through the escape valve. A large flow of gas flushes out the carbon dioxide. This results in minimal disturbance of blood carbon dioxide. But it is expensive, and with inflammable agents it may produce a distinct fire hazard (explosion) because of the dryness of the gases (even though bubbled through water) and their escape into the room.

In *B* the flow of gas is less than the respiratory volume. Part of the exhaled carbon dioxide-laden gas passes out through the escape valve, and part returns to the bag and is reinhaled. Partial rebreathing saves gas and thus reduces cost, but it causes carbon dioxide to build up in the blood. This is undesirable in itself and may trouble the surgeon by increasing the depth of breathing.

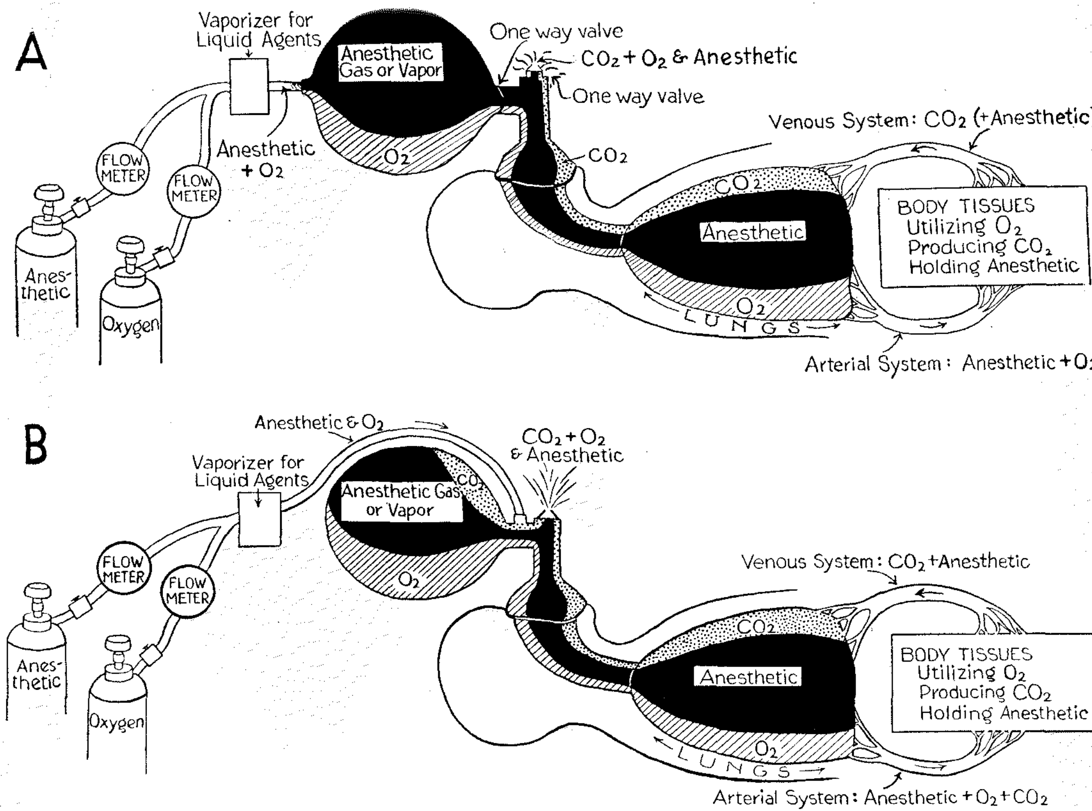

Fig. 40.—*A*, rapid flow with no rebreathing. *B*, moderate flow with partial rebreathing

Carbon Dioxide Absorption Technic

The systems shown in figure 41 allow no escape of gas. Carbon dioxide is removed by soda lime or some other chemical absorber. The oxygen consumed by the patient is replaced by slow flow from the cylinder. Both the fire hazard and the expense are greatly reduced.

From the standpoint of military medicine, however, the most important advantage of the absorption technic is the reduction in the bulk and weight of containers for gases and ether and the simplicity and small size of the apparatus necessary. With both the English and the Australian expeditionary forces, anesthetists have reported (1941) on the usefulness of gas anesthesia for the seriously wounded and the imperative need for carbon dioxide absorption equipment to conserve supplies. The to and fro arrangement is preferred because of its simplicity.

The essential equipment is shown in figure 41. For brief administration in connection with minor operations, the meters and the vaporizer are not necessary. However, for general use, small meters (diagram on left, p. 77) for the accurate measurement of oxygen, nitrous oxide and cyclopropane can be constructed. A vaporizer similar to that illustrated in the diagram to the right on page 77, in which abundant volatilization of liquid agents is secured, can be inserted between the breathing bag and the canister.

Essentials in the application of the technic are:

1. Unobstructed breathing in (*a*) upper respiratory tract and (*b*) apparatus.
2. Absence of leaks (*a*) in apparatus and (*b*) between apparatus and patient.
3. Minimization of dead space by the use of (*a*) small masks and (*b*) short connections with artificial airways.
4. Use of a satisfactory alkali to absorb carbon dioxide.

The Absorber.—Soda lime or an equivalent especially made for the purpose is essential. The size of the granules and the size and shape of the container must be correlated so that (*a*) adequate contact for carbon dioxide absorption takes place and (*b*) resistance to breathing is minimal. Five hundred grams of suitable soda lime properly arranged in a respiratory system and "rested" between administrations

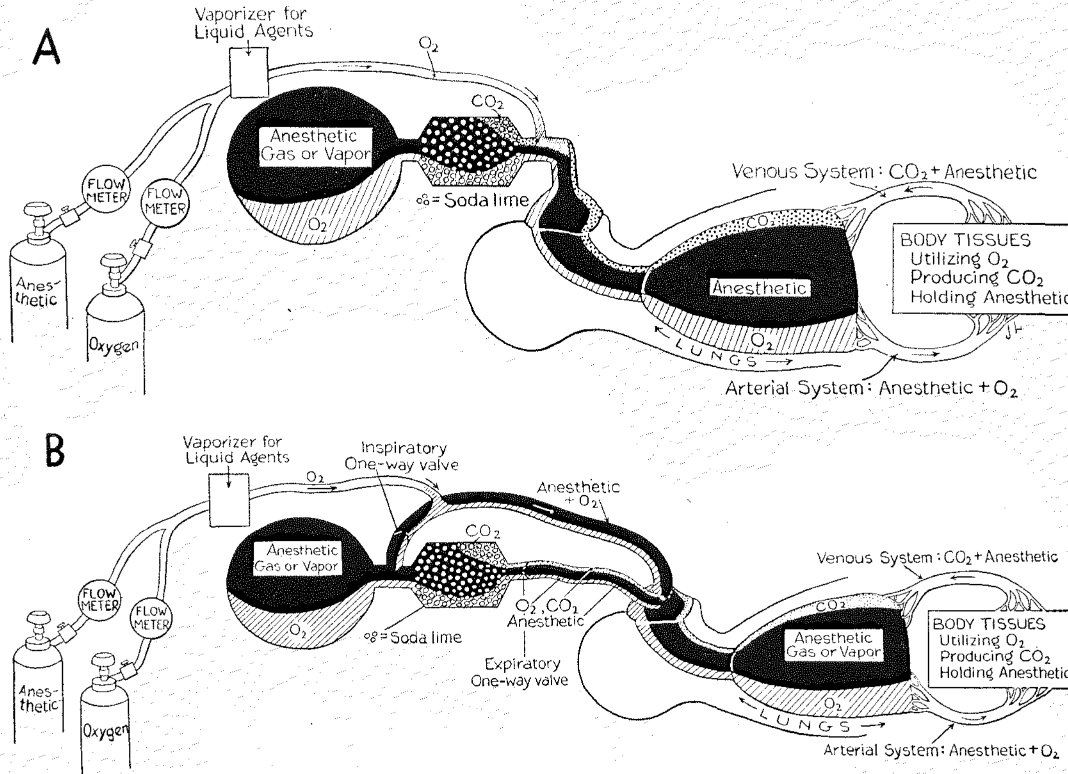

Fig. 41.—*A*, "to and fro" method. *B*, circuit method.

will absorb a major portion of the carbon dioxide produced by the average adult patient during eight to ten hours of anesthesia. Its exhaustion is determined by the clinical signs of an excess of carbon dioxide. These are: a marked increase of respiratory volume, a slight increase in the respiratory and pulse rates, an increase in systolic and pulse pressures or slight evidence of a beginning convulsion. Remember that drug depression may mask these signs of an excess of carbon dioxide. When in doubt, insert a fresh canister of alkali.

Pillows.—A frequent difficulty encountered by those unfamiliar with the to and fro absorption technic is in maintaining an air-tight contact of the mask with the patient's face. To overcome this difficulty, when the patient is in the dorsal position, place a large soft pillow under the head but not under the shoulders (a round-shouldered patient may require more than one pillow). Turn the patient's head to the right, fluff the pillow at its right end and allow the distal end of the canister to rest on the pillow while the mask rests on the face. To adjust the contact of the mask with the face, rotate the patient's head slightly toward the right or the left until all leaks are eliminated (see fig. 69, p. 135). With the patient in an awkward position other than the dorsal, it may be necessary to use a *very short*, large diameter, flexible tube between the mask and the canister. Such a connection must add only a minimum of dead space and must not be allowed to kink.

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EXCESS OF CARBON DIOXIDE, NOT DEPLETION, IS THE DANGER DURING THE USE OF THE CARBON DIOXIDE ABSORPTION TECHNIC.

AGENTS

Chloroform.—This agent can be given by open mask, vapor, semiclosed or closed technics. With it one can procure rapid induction of anesthesia and relaxation in robust patients without preliminary administration of depressive drugs. It should be used with caution because of its potency.

In the open technic, the mask should consist of not more than six layers of gauze or one of flannel. The eyes must be well protected; there should be no other covering of face or mask.

With semiclosed or absorption methods, chloroform is often used as an adjuvant to nitrous oxide. Its administration is also used as an induction to ether anesthesia.

Respiration is quiet and depressed.

Mixtures with ether must be regarded as dilute chloroform and not as fortified ether.

When chloroform is used for induction only, the change to ether should be made as soon as surgical anesthesia is reached, and a change to a fresh mask is made at that time.

Inflammable agents can always ignite; only rarely does chloroform kill.

Ethyl Chloride.—This anesthetic can be used by open, semiclosed and closed methods. It is almost as potent as chloroform and must be used with caution. It easily produces muscular spasm if any lack of oxygen occurs. It is useful chiefly for induction before the use of ether and for short procedures. Maintenance of the anesthesia for over fifteen minutes is not advisable.

Divinyl Ether.—It can be used by open, semiclosed and closed methods. It is intermediate in potency between ethyl chloride and diethyl ether. It easily produces muscular phenomena. It is useful chiefly for short operations or as an adjuvant to nitrous oxide. Maintenance of the anesthesia for over thirty minutes is not advisable.

Diethyl Ether.—This drug can be used with open, vapor, semiclosed or closed methods. Though an agent of full potency, it is slow in action and less potent than the aforenamed agents. It serves as a respiratory stimulant and irritant in light anesthesia. The secret of success in its administration is slow progressive concentration of the vapor in the presence of a perfect airway until the desired plane is reached.

Cyclopropane.—This agent can be used by all methods, but the absorption technic is desirable for safety and economy. The drug is very rapid in action. It is not an irritant to the respiratory mucosa. It is not a respiratory stimulant in light anesthesia; therefore respiration may fail before suppression of reflexes and relaxation are reached. The usual practice is to fill a closed system partially with air containing an excess of oxygen and then admit the gas progressively and slowly until the desired plane is reached.

Ethylene and Nitrous Oxide.—Either of these drugs may be given by means of semiclosed or closed systems. The two agents are of marginal potency and rapid action. Deep anesthesia cannot be achieved. Attempts to deepen the anesthesia usually result in oxygen lack.

For efficient anesthesia, the agent must replace the nitrogen in the tissues of the body, and the nitrogen must be eliminated from the apparatus.

Ethylene is explosive, and is better administered by the absorption technic. When the absorption technic is in use, the bag must be periodically emptied and refilled with the agent. Air must not be allowed to leak in and dilute the mixture.

If adequate anesthesia cannot be obtained with these agents, it is wiser to supplement them with a more potent agent than to reduce the oxygen content of the mixture. The scope of these agents may be widened by the use of ether with them.

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V

Local Anesthesia

PROCAINE HYDROCHLORIDE is an old and well established agent for producing local anesthesia. It will be emphasized in the following discussion. Other drugs useful for this purpose are referred to in table 6 (p. 44).

Toxicity of Anesthetic Solutions

Symptoms

1. Syncope, faintness, dizziness or sudden severe headache.
2. Apprehension.
3. Shortness of breath or suffocation.
4. Nausea.
5. Palpitation.
6. Precordial pain.

Signs

1. Pallor.
2. Cyanosis.
3. Diaphoresis.
4. Vomiting.
5. Extreme change of the pulse rate—usually slower but sometimes more rapid.
6. Change of blood pressure.
7. Talkativeness, excitation and convulsions.
8. Unusual skin wheal.
9. Air hunger.

Prophylaxis

1. Inject the solution of procaine hydrochloride slowly.
2. Aspirate frequently to avoid intravascular injection.
3. Combine the solution of procaine hydrochloride with a vasoconstrictor so as to decrease the rate of absorption.
4. Give barbiturates to prevent possible convulsions (see "Barbituric Acid Derivatives," pp. 38-41).
5. Use the weakest effective solution. It has been suggested by some anesthetists that the toxicity increases in geometric progression with the concentration.
6. Abandon the injection at signs of idiosyncrasy.

Treatment of Reactions

Mild:

1. Interrupt the injection.
2. Give continuous inhalation of oxygen. (Make sure of an efficient respiratory exchange.)

Severe:

1. Interrupt the injection.
2. Do immediate effective artificial respiration, preferably with oxygen and positive pressure. (Make sure of an efficient respiratory exchange.)
3. Lower the head of the patient.
4. Have the assistant give a barbiturate intravenously.

TECHNIC FOR LOCAL AND BLOCK ANESTHESIA

The Following Principles of Technic Relate to the Injection of Procaine Hydrochloride

1. Avoid intravascular injection by carefully introducing needles into the tissue and by carefully aspirating in two planes with the plunger of the syringe before injecting procaine hydrochloride to produce local anesthesia.

2. Avoid injection close to very vascular regions, such as the site of a hemangioma.

3. Test all needles for imperfections in order to avoid breakage when they are introduced into the tissues.

4. Preliminary medication is very valuable because it relieves fear and anxiety and reduces pain. Some of the more commonly used drugs are morphine, scopolamine and several derivatives of barbituric acid. The barbiturates are used chiefly to decrease nervousness and to counteract the tendency of toxic doses to produce convulsions. They have no prophylactic effect on circulatory reactions. Too much preliminary sedation makes for depressed respiration, restlessness and lack of cooperation. The latter may interfere with satisfactory tests for anesthesia.

5. Procaine hydrochloride is usually used in 0.5 per cent, 1.0 per cent or 2.0 per cent solution, the last concentration being used least extensively. Physiologic solution of sodium chloride is the diluent commonly employed. Healthy adults will usually tolerate 175 to 225 cc. of a 0.5 per cent solution of procaine hydrochloride or 100 to 125 cc. of a 1.0 per cent solution and 25 to 50 cc. of a 2.0 per cent solution. Patients who are cachectic or debilitated will not tolerate the same amounts, and the doses must be reduced by at least 30 or 40 per cent.

6. Procaine hydrochloride solution should be warmed to body temperature, because if it is cold the onset of anesthesia will be delayed.

7. Vasoconstrictors such as epinephrine, cobefrin (corbasil) and neo-synephrin are incorporated frequently in solutions of procaine hydrochloride in order (*a*) to prevent too rapid absorption of the local anesthetic, thereby prolonging anesthesia and reducing toxic effects, and (*b*) to promote hemo-

stasis. However, for local anesthetizing procedures on the fingers and toes and in cases of coronary disease and hyperthyroidism, vasoconstrictors are usually omitted.

8. Toxic reaction from local anesthetics, characterized by a drop in blood pressure, pallor, sweating, weak pulse and occasionally by nausea and vomiting, may be of two types: (*a*) circulatory or (*b*) neurologic, characterized by talkativeness, excitation and convulsions.

9. Circulatory reactions from local anesthetics should be treated by administering oxygen and certain analeptic agents, such as ephedrine or epinephrine. In neurologic reactions oxygen should be administered, by intermittent inflation if necessary, and a soluble barbiturate, such as sodium amytal or pentothal sodium, should be administered intravenously until the reaction is controlled.

10. Patients who allege that they are sensitive to local anesthetics should be given a preliminary intradermal test. Briefly this consists in making three intradermal wheals on a suitable cutaneous surface, using a control wheal of physiologic solution of sodium chloride; adjacent to this, an intradermal wheal is made with a 1 per cent solution of procaine hydrochloride, and closely adjacent to the latter wheal a third intradermal injection is made with a vasoconstrictor, such as epinephrine or cobefrin. After five minutes the intradermal wheals are examined, and if there is any redness about the procaine hydrochloride wheal, one is justified in assuming that the patient is probably sensitive to the agent. The intradermal wheal made with a vasoconstrictor will naturally be blanched for some time, but if the patient reacts unfavorably to the vasoconstrictor, the objective signs of tremor, pallor and nervousness will be easily detected, and the patient will complain of such subjective sensations as faintness, palpitation and dyspnea.

11. The anesthetist should watch the patient throughout the operation. A record of blood pressure, pulse rate and respiratory rate should be kept throughout the period of injection and drug effect. A gas machine should be available for the administration of oxygen, for artificial respiration or for the induction and maintenance of general anesthesia should the occasion demand it.

Method of Raising Intradermal Wheal

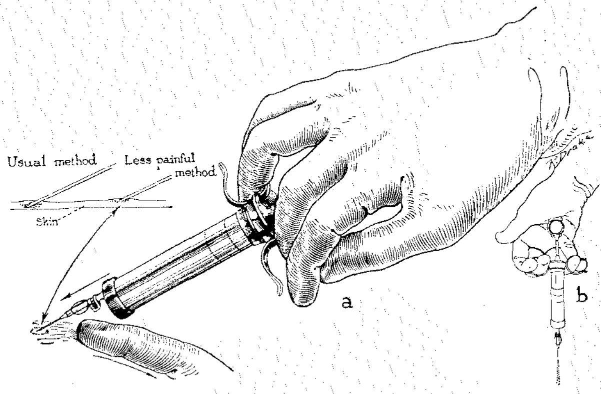

Fig. 42.—The intradermal wheal is made less painfully if the bevel of the needle is held against the skin. Firm pressure on the plunger is maintained while the needle is advanced to and into the skin.

FIELD BLOCK

The field block is a more satisfactory method to patient and surgeon than infiltration anesthesia. It can be done in nearly all anatomic situations.

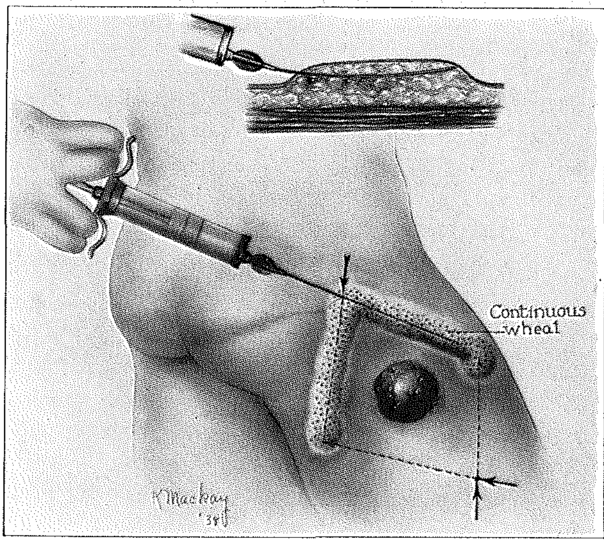

Fig. 43.—The method of making a continuous intradermal wheal. Through a primary skin wheal, a long needle is extended, with the bevel up, along the subcutaneous layer of tissue to a point where the distal intradermal wheal is to be made. Here the point of the needle is brought to bear against the external skin by pressure of the finger or by skin tension, and is introduced into the subcuticular layer, where the solution is deposited. (For the intent of this procedure, solution deposited in the subcutaneous layer is valueless.) As the needle is withdrawn, a series of coalescing wheals is made in the same manner, producing the orange-peel appearance of the skin. To complete the block, walls of anesthetic solution must be deposited in deeper tissues, extending from the row of skin wheals to a point sufficient to cut off all deep innervation.

AN ADEQUATE FIELD BLOCK SATISFIES BOTH SURGEON AND PATIENT.

SPINAL ANESTHESIA

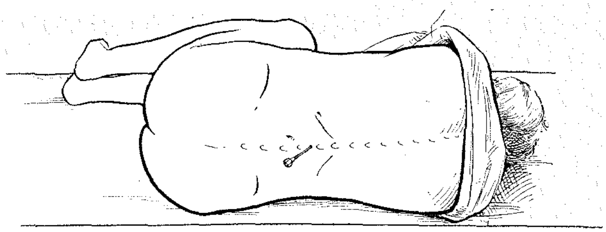

Fig. 44.—Position of the patient for administration of a spinal anesthetic. A line drawn between the highest points on the iliac crests crosses the spine of the fourth lumbar vertebra.

Many technics and many agents are used for producing spinal anesthesia. Meticulous attention to detail is most important. Never try to combine a detail of one technic with another technic without due consideration. Variations in the length of action, toxicity and specific gravity of solutions of the several drugs make imperative an individual technic for each agent.

Use of Procaine Hydrochloride

Dosage.—Average is 1 mg. per pound of body weight (total dose should never exceed 200 mg.). Factors modifying dosage:

1. Old and debilitated patients often require less.
2. Young and vigorous ones may require more.
3. The longer the operation the larger the dose.
4. The higher the operation the larger the dose.

Site of Injection.—One of the lumbar interspaces should be used to avoid possible injury to the spinal cord by the needle. For operations in:

1. Upper abdomen—1st lumbar space (solution may be injected with bevel of the needle directed upward).
2. Lower abdomen—2d lumbar space.
3. Perineum and below—3d lumbar space (solution may be injected with the bevel of the needle directed downward).

Rate of Injection.—The diffusion of the solution of procaine hydrochloride in the spinal fluid is influenced by the rate of injection—the faster the injection the further the solution diffuses.

Volume.—Concentrated solutions result in (1) longer anesthesia, (2) greater relaxation and (3) possible permanent damage to nerve tissue (a solution of procaine hydrochloride stronger than 10 per cent must not be used).

Dilute solutions result in (1) shorter anesthesia, (2) less relaxation and (3) less damage to nerve tissue.

The larger the volume injected the greater the distribution in the spinal fluid.

TABLE 10.—*Dosage and Dilution of Procaine Hydrochloride in Spinal Anesthesia* *

Operation	Lumbar Vertebrae Between Which Injection Is Made	Dose of Procaine Hydrochloride (Mg.)	Total Dilution in Physiologic Solution of Sodium Chloride and Spinal Fluid
Hemorrhoidectomy	3 and 4	50 to 100	2.5 cc
Perineal prostatectomy	3 and 4	80 to 120	2.5 cc
Herniorrhaphy	2 and 3	120 to 150	3.5 cc.
Appendectomy	2 and 3	120 to 150	4.0 cc.
Operation for ruptured duodenal ulcer	1 and 2	120 to 175	6.0 cc.
Cholecystectomy	1 and 2	150 to 200	6.0 cc.

* A spinal needle, gage 20 to 22, is used. The rate of injection is 0.50 cc. each second.

Continuous spinal anesthesia has proved to be a useful technic since its introduction in 1940. It embodies the principle of producing spinal anesthesia by the periodic administration of the drug as needed. A flexible needle is left in place and connected to a syringe by small caliber rubber tubing. Special equipment, including a special mattress, must be used.

REFERENCE

1. Lemmon, W. T.: A Method for Continuous Spinal Anesthesia, Ann. Surg. **111**:141-144 (Jan.) 1940.

NERVE BLOCKS

The specific nerve blocks described in this section have been chosen because of their simplicity and usefulness. The blocks used in maxillofacial surgical procedures have not been considered, as they are usually amply described in conjunction with the description of the surgical technic. All the peripheral nerves as well as the cranial nerves are subject to blocking with anesthetic solutions. The technics not described in the following pages may be found in the references on page 119.

Block Anesthesia of Half of Scalp

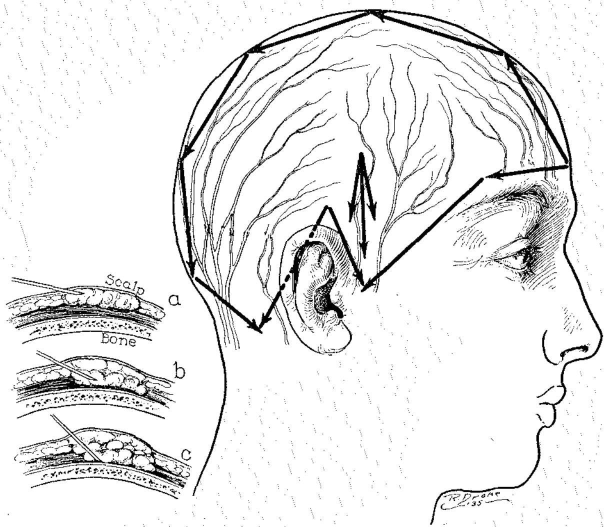

Fig. 45.—The three arrows above the auricle of the ear show the method of injecting the solution into the temporal fossa in addition to the rest of the field block. The inserts, *a*, *b* and *c* illustrate the intradermal, intramuscular and pericranial infiltration, respectively. All three layers must be infiltrated to produce satisfactory anesthesia.

Cervical Plexus Block

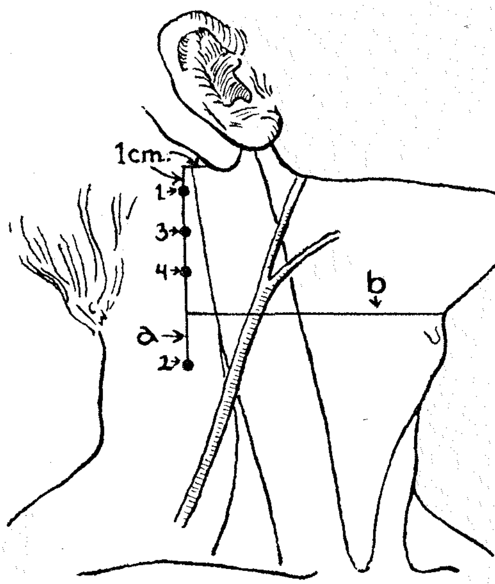

Fig. 46.—The landmarks for a cervical plexus block by the lateral route are shown. Site 1 is 1 cm. posterior and caudad to the mastoid process. Site 2 is Chassaignac's tubercle, which is easily felt in a majority of subjects. Project a straight line (*a*) between sites 1 and 2. Locate the upper border of the thyroid cartilage and project a line (*b*) posteriorly until it cuts line *a*. This point of intersection marks the transverse process of the fifth cervical vertebra. Divide the distance between site 1 and this process into three equal parts, raising a skin wheal with a solution of procaine hydrochloride at each division point (1, 3 and 4). These points mark the location of the transverse processes of the second, third and fourth cervical vertebrae. Inject 5 cc. of a 1 per cent solution of procaine hydrochloride as the needle is held lightly in contact with the transverse process of each of the last-named three vertebrae. Allow 3 cc. of the solution to be injected as the needle is withdrawn. The block is not complete unless the superficial nerves are blocked. This is done by depositing about 15 cc. of the solution subcutaneously and subfascially along the posterior margin of the sternocleidomastoid muscle.

BLOOD VESSELS IN THE NECK ARE LARGE AND NUMEROUS. INJECTIONS IN THIS REGION SHOULD BE DONE BY AN EXPERT.

Block Anesthesia of Upper Extremity—Brachial Plexus Block

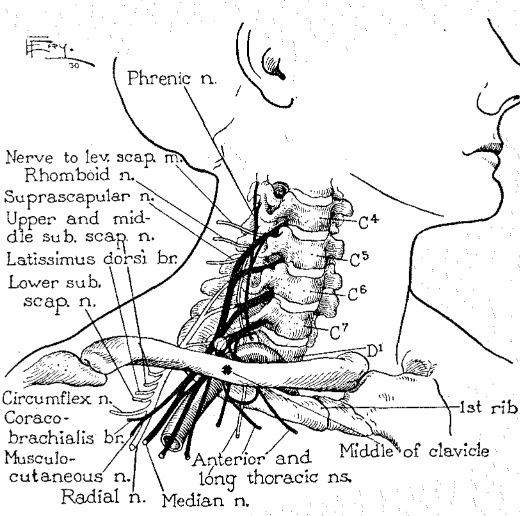

Fig. 47.—Brachial plexus.

The injection to affect the brachial plexus must be made in a vascular area, near large blood vessels and important nerve trunks, including those which innervate the muscles that control the delicate movements of the hands and fingers. The pleura is near the site of injection. The needle must deposit solutions between two fascial layers which are in close proximity. Failure of the block is therefore possible.

The shoulder and upper arm are not included in the block. To extend insensibility to these areas, accessory injections must be given.

Brachial plexus block is best used (1) when the patient's cooperation is needed for identification of severed tendons and (2) when inhalation anesthesia is contraindicated.

Labat recommended that the patient lie on his back with the head turned toward the side opposite the site of injection. The arm on the side on which the injection is to be made should be held close to the side of the body so as to depress the clavicle as much as possible. After the middle point of the clavicle has been ascertained, a wheal should be raised 1.5 cm. above it by injecting a 0.5 per cent solution of procaine hydrochloride. (See figs. 47 and 48.) A 50 mm. needle of 20 or 21 gage, unattached to a syringe, should then be gently introduced downward, backward and inward (fig. 48). The patient should be instructed to tell the operator as soon as he feels any paresthesias in his arm and hand, because when these are elicited 20 cc. of a 2 per cent solution of procaine hydrochloride with epinephrine hydrochloride 1:2,600 should be injected without deflecting the point of the needle. Figure 49 shows the areas of anesthesia.

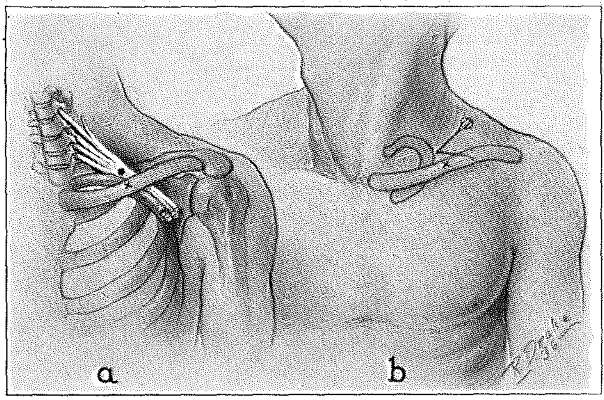

Fig. 48.—Relationship of the brachial plexus and the clavicle and subclavian artery. In *a* the *x* marks the midpoint of the clavicle and the dot the site of injection; *b* shows the relationship of the first rib to the site of injection.

If paresthesias are not obtained after the needle has been inserted 2.5 to 3 cm., the needle will ordinarily contact the upper surface of the first rib, unless the general direction has been missed entirely. If the needle rests on the first rib and no paresthesias have been obtained, it is possible that the needle has passed between the branches of the brachial plexus without contacting them; it should be withdrawn and the direction slightly changed before reintroduction. The usual error is that the needle has been placed too far laterally from the subclavian artery and clavicle in an effort to avoid the vessel. By compressing the subclavian artery with the index finger of the opposite hand and directing the needle closer to the clavicle, paresthesias will usually be obtained before contacting the rib again. In the absence of paresthesias it is unwise to attempt multiple blind punctures in this region, because of the danger of trauma to the blood vessels. Labat has suggested a technic that may be used when paresthesias cannot be obtained. This consists of injecting 10 cc. of a 2 per cent solution of procaine hydrochloride beneath the fascia overlying the brachial plexus in the direction of the first rib, and supplementing this by injecting 5 cc. of the same solution at the lateral margin of the first rib and 5 cc. toward the transverse process of the sixth cervical vertebra. The supraclavicular region is then massaged gently for a few minutes in order to hasten diffusion.

A bracelet of skin wheals proximal to the area of operation (see fig. 52, p. 101) may be needed to supplement the brachial plexus block.

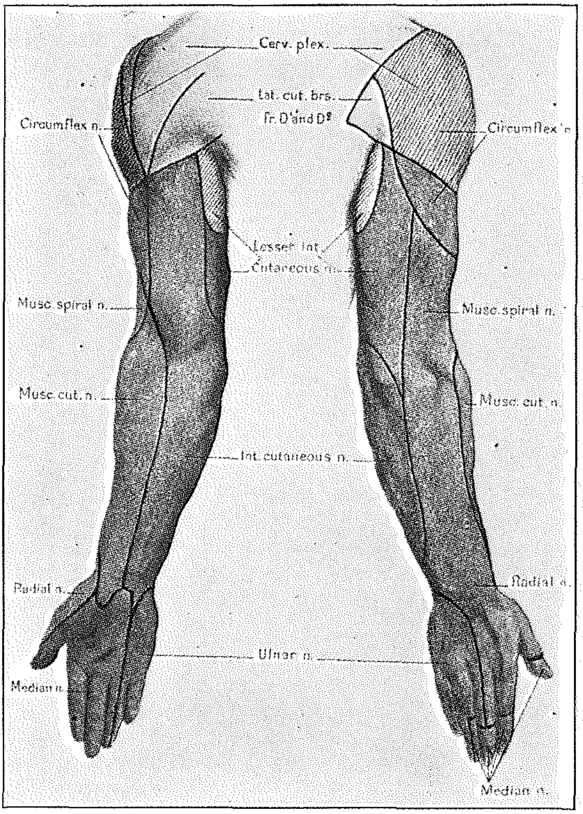

Fig. 49.—Brachial plexus block by the supraclavicular route: dark area, the resulting zone of anesthesia; gray area, hypesthesia.

NOTES

Nerve Block at Elbow

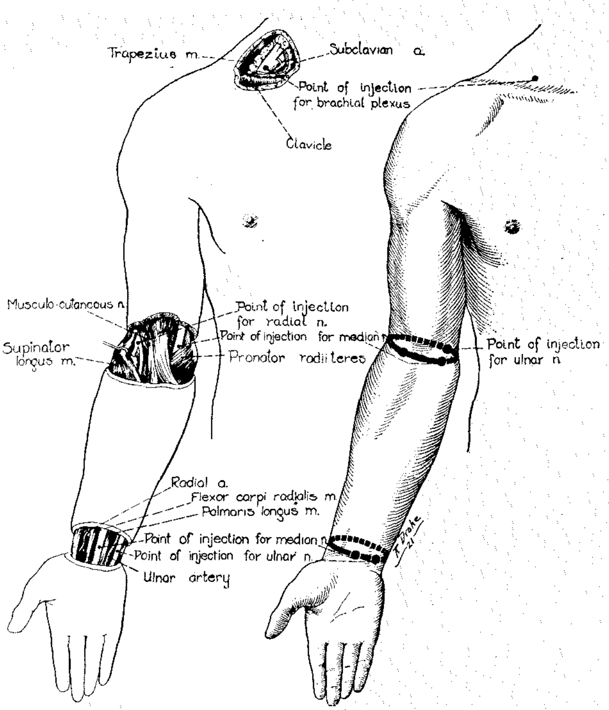

Fig. 50.—The sites of injection of solution of procaine hydrochloride for blocking the median, radial and ulnar nerves at the elbow are shown. This is satisfactory when anesthesia of the hand is desired and a brachial plexus block is contraindicated, and the block at the wrist is too close to the wound or operative field.

Block Anesthesia of Hands and Feet

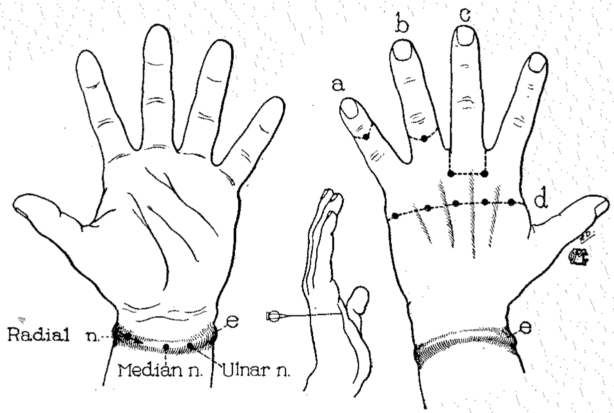

Fig. 51.—Sites of injection for blocking the three main nerves which supply the hand: (*a*) For anesthesia of the distal phalanx. (*b*) For anesthesia of the middle and distal phalanges. (*c*) For anesthesia of the whole finger including the metacarpophalangeal joint. (*d*) For anesthesia of the four fingers of the hand. One injects from the skin of the dorsal surface to the skin of the palmar surface directly through the hand, as shown in the insert. (*e*) If one desires to anesthetize the entire hand distal to the wrist, a bracelet-like injection is accomplished. The intradermal and subcutaneous part of the injection encircles the wrist, while the deep part of the injection includes the radial, median and ulnar nerves. One per cent solution of procaine hydrochloride is used for the deep part of the injection, the sites for which are indicated, and 0.5 per cent solution of procaine hydrochloride is used for the superficial part of the injection.

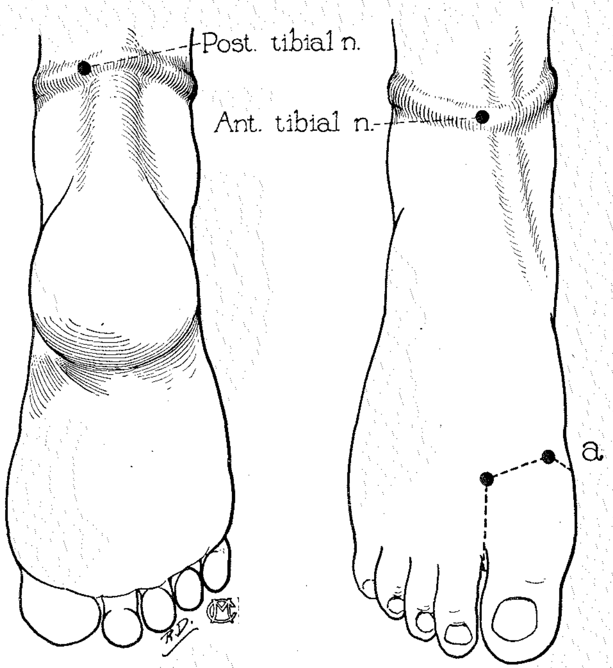

Fig. 52.—Site of injection of the anterior and posterior tibial nerves and (*a*) the type of block used for bunion operations.

Segmental Nerve Blocks

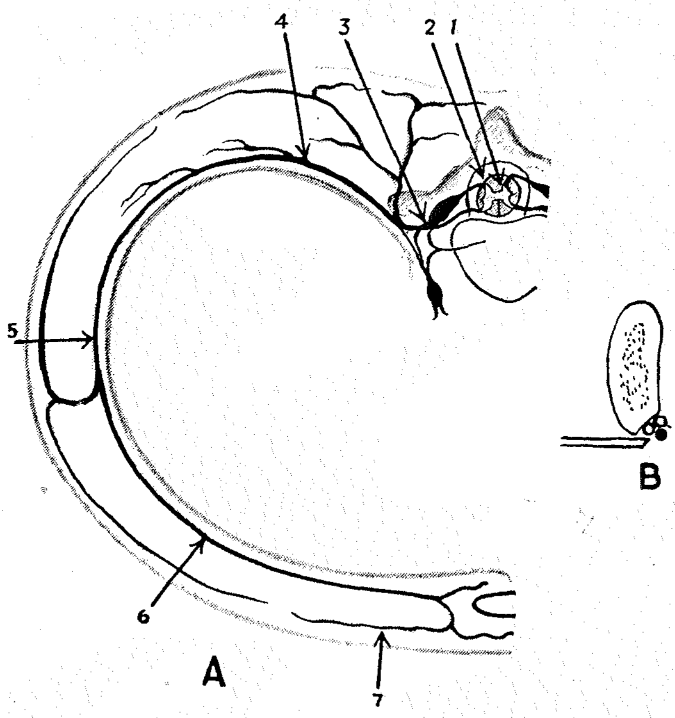

Fig. 53.—*A,* points along the course of a spinal nerve at which anesthesia may be produced by various methods: *1,* intradural or spinal; *2,* peridural; *3,* paravertebral; *4,* intercostal block at costal angle; *5,* intercostal block at the midaxillary line; *6,* abdominal block; *7,* infiltration. *B,* sagittal view of a rib with the vessels and intercostal nerve, showing the position of the needle for intercostal block. Blocking each of the lower six intercostal nerves bilaterally at the midaxillary line with 5 cc. of a 1 per cent solution of procaine hydrochloride, when carefully done, causes paralysis of the transversalis abdominis muscle and of the muscles of the abdominal wall, thus providing relaxation of the peritoneum.

For *fractured ribs* the injection just described may be made at a considerable distance posterior to the site of fracture. Marked and prolonged comfort may thus be secured.

Abdominal Wall Block

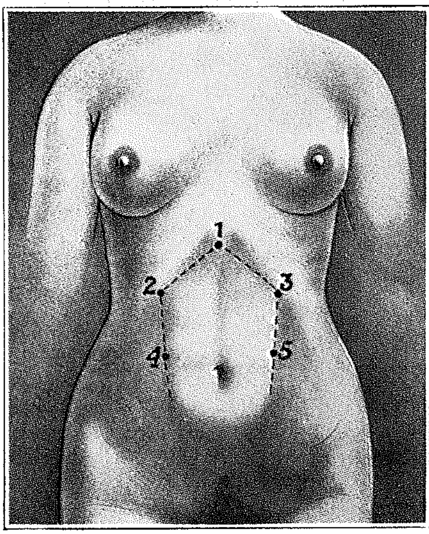

Fig. 54.—Abdominal field block.

With the patient lying in the supine position, wheals (1 to 5) are raised with a 0.5 per cent solution of procaine hydrochloride along the costal margin and the lateral margins of the rectus abdominis muscles: one at the tip of the xiphoid process; one on each side, at the level of the tenth costal cartilage, where the lateral margin of the rectus muscle crosses the costal margin; the last two, one on each side, on the lateral margin of the rectus muscle, a little higher than the umbilicus (fig. 54). For the sake of convenience, more than two wheals may be raised on the lateral margin of the rectus, especially in very fat patients.

The needle is attached to the syringe filled with a 0.5 per cent solution and is passed through one of the lowest wheals; it is gently advanced in the superficial fascia in a direction slightly inclined inward toward the rectus muscle. As soon as the needle touches the rectus sheath, it is quickly pushed in from 0.5 to 1 cm. farther, and about 2 cc. of the solution is injected without moving (fig. 55). The needle is then drawn back until its point reaches the subcutaneous tissue, and is reintroduced several times, more and more obliquely upward, then downward, with a small quantity of the solution being injected each time within the rectus sheath. The needle is withdrawn and passed through the other wheals and the solution distributed fan-wise higher up and in the muscle layer along the costal margin. When the deep injections have been completed, the solution is distributed subcutaneously along the lines, joining all the wheals together except the last two, and the region lightly massaged to spread the solution within the tissues. Not more than 100 cc. of the 0.5 per cent solution is necessary for an abdominal field block.

The rectus sheath offers to the point of the needle a resistance which must be felt before the needle is advanced any farther. This contact is, besides, always noticed by the patient as a sharp prick.

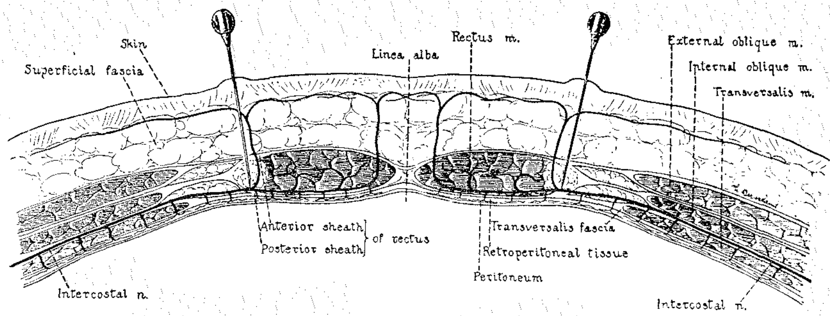

Fig. 55.—Cross section of a part of the abdominal wall, showing the method of making deep injections within the rectus sheath.

Block Anesthesia for Inguinal Hernia

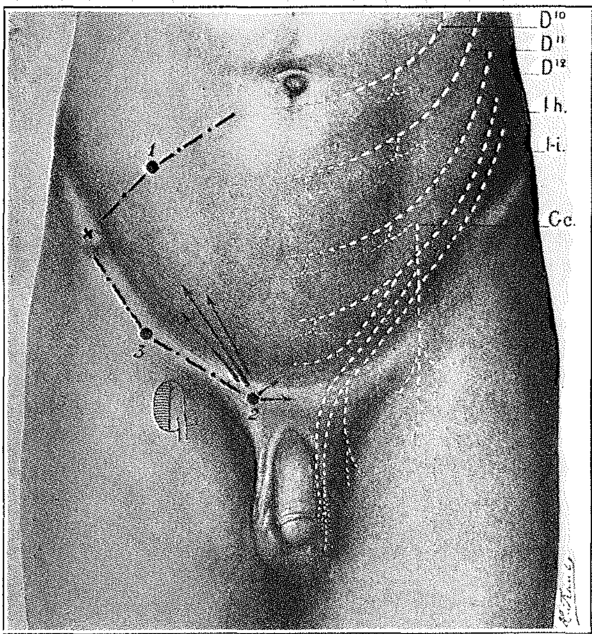

Fig. 56.—Field block for unilateral reducible hernia. On one side the technic is illustrated; on the other, the nerve supply. *1,* parailiac wheal; *2,* pubic wheal; *3,* subinguinal wheal; *x* anterior superior iliac spine.

With the patient lying in the dorsal decubitus position, three wheals are raised at 1, 2 and 3 (fig. 56). Wheal 1, called the "parailiac wheal," is placed about 2.5 cm. above and medial to the anterior superior spine of the ilium; wheal 2, called the "pubic wheal," lies just above the pubic spine; wheal 3, called the "subinguinal wheal," is raised just below Poupart's ligament and lateral to the femoral artery.

The needle is passed through the parailiac wheal (no. 1), and a 1 per cent solution of procaine hydrochloride is distributed fanwise within the muscle layers down to the fascia of the transversalis abdominis muscle in a plane perpendicular to the surface of the skin and extending from the crest of the ilium toward the umbilicus, the last injections being made within the rectus sheath at a short distance from the umbilicus (fig. 57). A subcutaneous infiltration made along this plane completes the wall of anesthesia which blocks the iliohypogastric, ilioinguinal and the two lower thoracic nerves. From 30 to 40 cc. of the 1 per cent solution is used in this injection in the average case. The needle is then passed through the pubic wheal (no. 2), and deep injections are made, with about 8 cc. of the same solution, along the horizontal ramus of the pubis, on each side of the spermatic cord, into the pubic attachment of the rectus muscle and extending a little beyond the midline. Through the same site of puncture subcutaneous injections are then made along the horizontal ramus of the pubis to a point 3 to 4 cm. beyond the midline, using about 5 cc. of the same solution for each of these injections. The needle is next inserted through the subinguinal wheal (no. 3) and deep injections are made beneath Poupart's ligament, followed by subcutaneous injections parallel with and along this ligament. About 10 cc. of the 1 per cent solution is needed for this.

The spermatic cord is then grasped between the thumb and the index finger at the level of the external inguinal ring, or at the point where it crosses the pubis, and the needle is inserted through the pubic wheal (no. 2). The position of the operator for the injection of the cord depends on the side to be injected, the injection being best made from the pubic spine upward. The cord structures are thus

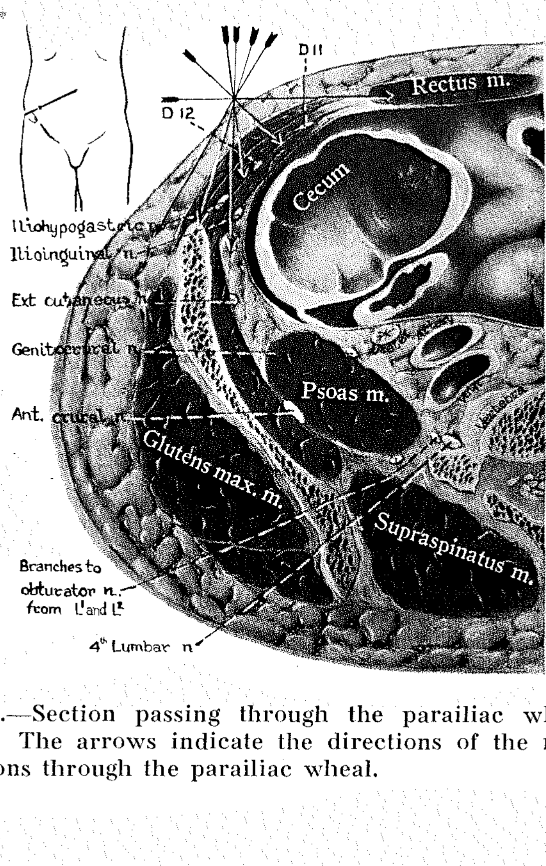

Fig. 57.—Section passing through the parailiac wheal and the umbilicus. The arrows indicate the directions of the needle during the injections through the parailiac wheal.

transfixed in an upward direction and injected with about 5 cc. of the 1 per cent solution, care being exercised not to traumatize these structures by multiple punctures. Never try to inject the cord in irreducible hernia.

The last injections are made at the margins of the internal ring. They surround the neck of the sac and are intended to block the genitocrural nerve. If the internal ring can be easily defined by palpation, the needle is attached to the syringe filled with the 1 per cent solution, is passed through the pubic wheal (no. 2) and advanced subcutaneously to a point just medial to the margin of the ring. The fascia is then pierced at this point and a small quantity of the solution injected beneath it. Similar injections are made lateral to and above the margins of the ring, using from 5 to 10 cc. of the 1 per cent solution.

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Transsacral Block

(Continued on p. 108)

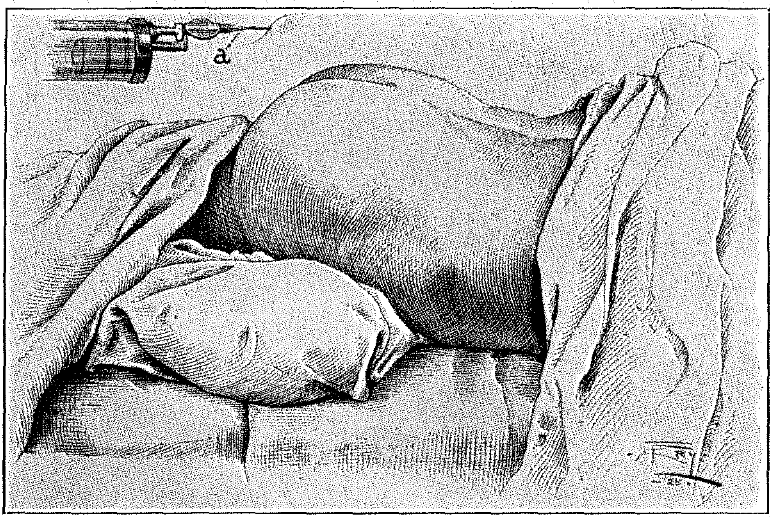

Fig. 58.—Proper position of the patient on the table for the performance of sacral block. (*a*) The position of the syringe when the initial skin wheal is raised prior to the injection of the anesthetic solution into the caudal canal.

Transsacral Block

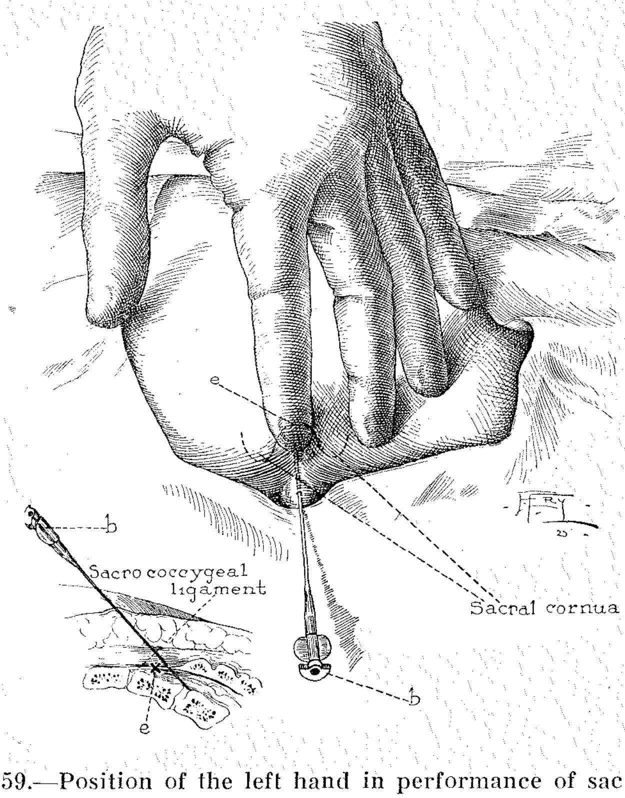

Fig. 59.—Position of the left hand in performance of sacral block: (*e*) position of the index finger in relation to the sacral cornua, and (*b*) introduction of a 50 mm. needle through the skin, subcutaneous tissue and sacrococcygeal ligament.

Transsacral Block

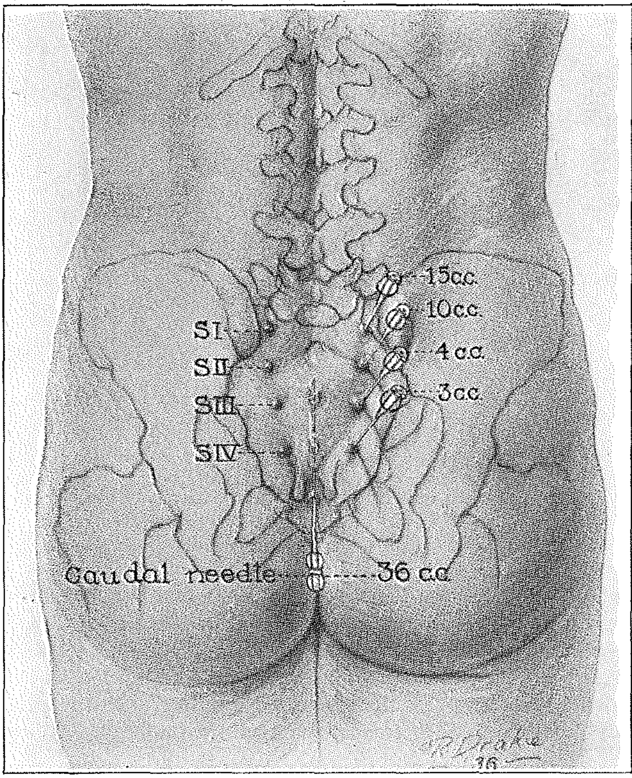

Fig. 60.—Transsacral block anesthesia. The drawing shows the soft tissue of the buttocks and the bony skeleton of the pelvis, with needles introduced into the sacral foramens and a larger needle introduced into the caudal canal (III). The average amounts of 1 per cent procaine hydrochloride solution used for this block are also illustrated. The injection is made while the patient lies prone with the pelvis elevated (see fig. 58). The foramen of the second sacral nerve is found about 1 fingerbreadth caudad, and an equal distance medial to, the posterior superior spine of the ilium. The third and fourth foramens are in line with the second, 1 fingerbreadth caudad. The first foramen is 1 fingerbreadth cephalad, and an equal distance medial to, the posterior superior spine. The caudal foramen is found by palpating the cornua of the sacrum with the index and middle fingers of one hand and palpating for the foramen between the cornua with the index finger of the other hand.

Block for Repair of Femoral Hernia or for Ligation of the Greater Saphenous Vein

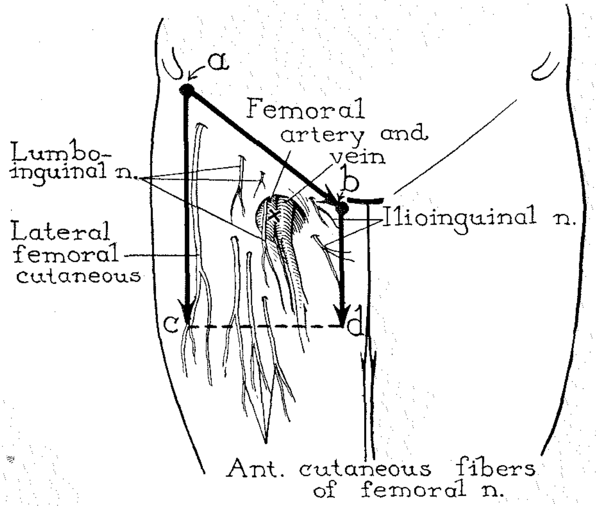

Fig. 61.—The sensory innervation of the anterior surface of the upper part of the thigh and the type of field block used for operations in this region, such as the repair of femoral hernia or the ligation of the greater saphenous vein. The injection is made as indicated by the direction of the arrows; that is, *a* to *b*, *a* to *c* and *b* to *d*. In a few instances it is necessary to inject between *c* and *d*. At the point marked *x*, 5 cc. of a 1 per cent solution of the anesthetic agent is deposited directly over the femoral artery and vein.

Sciatic Nerve Block

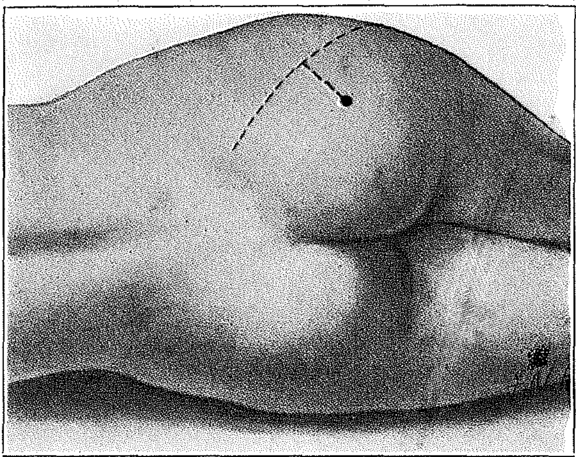

Fig. 62.—Procaine block of the greater sciatic nerve may be used for therapeutic purposes or diagnostically before the injection of other solutions in the treatment of sciatica.

With the patient in the lateral position and the side to be injected uppermost, the thigh is flexed as indicated. The axis of the femur then passes through the posterior superior iliac spine. A line is drawn from the upper end of the greater trochanter to the posterior superior iliac spine. From its midpoint a perpendicular line is now drawn downward and inward, and the point selected for injection is located on this line about 3 cm. from its origin. An intradermal wheal is produced with a solution of procaine hydrochloride. A 10 cm. needle is then placed on the syringe and introduced vertically. It is advanced gently until it impinges on the nerve, which lies from 5 to 8 cm. beneath the skin, causing paresthesia. If the first attempt fails, the needle is alternately withdrawn and advanced at slightly different angles, a procedure in which its point will generally strike the nerve. From 5 to 10 cc. of a 2 per cent solution of procaine hydrochloride is injected slowly, and ten minutes is allowed for anesthesia to develop.

Femoral Nerve Block

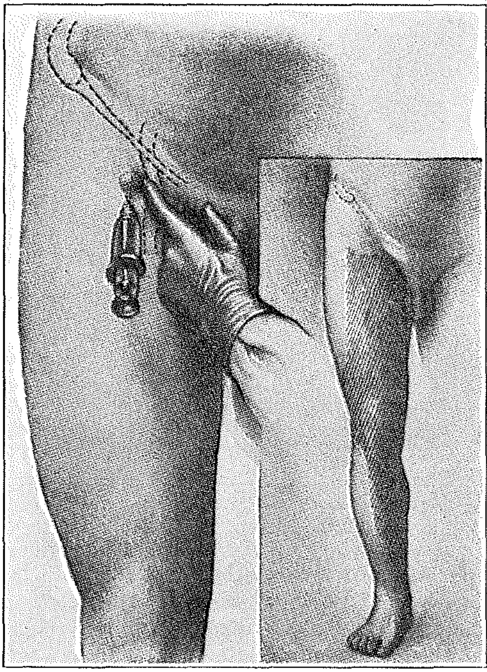

Fig. 63.—The femoral nerve arises from the lumbar plexus and emerges on the thigh beneath Poupart's ligament, medial to the external cutaneous nerve and just lateral to the large vessels of the thigh. It supplies the anterior medial aspect of the thigh, while its ultimate branches are distributed to a large area of skin on the knee and leg (insert). Just below Poupart's ligament the nerve lies beneath the deep fascia or, often, somewhat deeper in the iliac muscle.

In blocking this nerve, the femoral artery is first identified by palpation, and a wheal is raised with a 2 per cent solution of procaine hydrochloride just external to the course of the artery. The femoral artery is gently pressed mesially with the index finger of the free hand and kept in this position throughout the procedure. The needle is passed vertically through the wheal as the solution is injected, and the operator can recognize the piercing of the iliac fascia. Paresthesia is experienced by the patient when the nerve, which lies about 1 cm. deeper than the fascia, is struck. When this occurs 5 cc. of the anesthetic solution is injected without moving the needle. If paresthesia cannot be elicited after two or three attempts, anesthesia may generally be produced by injecting about 25 cc. of the solution fanwise into the muscle beneath the fascia and waiting a few minutes.

The insert shows the cutaneous distribution of the femoral nerve.

External Femoral Cutaneous Nerve Block

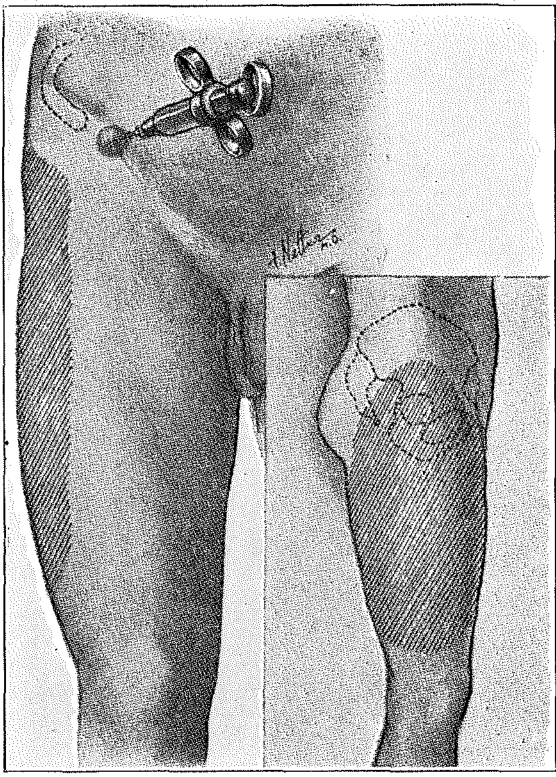

Fig. 64.—The external femoral cutaneous nerve emerges from the iliac fossa beneath Poupart's ligament onto the thigh and supplies, in addition to other tissues, the integument on the external aspect of the thigh (insert). This is the usual location from which to obtain skin grafts and fascial transplants.

In blocking this nerve, an intracutaneous wheal is first made with a 1 per cent solution of procaine hydrochloride 2 cm. below and mesial to the anterior superior iliac spine. The needle is introduced vertically and advanced downward gradually, injecting the anesthetic solution continuously, until its point strikes the iliac bone, where about 10 cc. of solution is deposited. The needle is then partially withdrawn and advanced several times, its point being directed alternately externally and internally as the solution is introduced. Thus a series of fanlike injections are made along Poupart's ligament, extending about 5 cm. from the anterior superior iliac spine.

The insert shows the cutaneous distribution of the external femoral cutaneous nerve.

Block Anesthesia of Leg and Foot

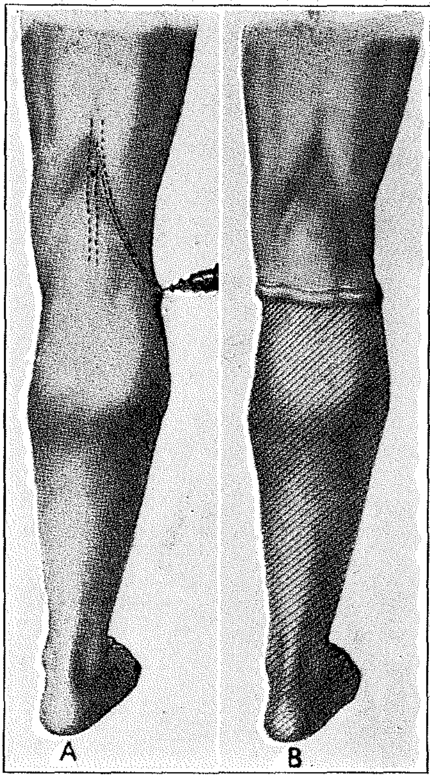

Fig. 65.—The leg from the knee down may be quickly and effectively anesthetized for most surgical procedures by blocking the internal and external popliteal nerves and producing a subcutaneous ring of anesthesia.

A shows the technic for blocking the internal and external popliteal nerves. 1. Internal popliteal nerve: With the patient in the prone position and the legs extended, the hamstring muscles stand out and are easily visualized. The angle formed by the biceps and semimembranous muscles at the upper end of the popliteal space is palpated and marked on the skin. On an imaginary line bisecting the angle a wheal is raised about 7 cm. above the bend of the knee. A 7 cm. needle is then passed through the wheal perpendicular to the plane of the skin. After perceiving the characteristic sensation as the needle point pierces the deep fascia, the operator proceeds gently, as the nerve lies about 1 to 1.5 cm. deeper. On striking the nerve, paresthesia is elicited, and 5 cc. of a 2 per cent solution of procaine hydrochloride is injected. Should the first attempt be unsuccessful, the needle may be partially withdrawn and introduced at slightly different angles, but caution should be exercised to prevent puncture of the popliteal vein, which lies medial and deep to the nerve. If the nerve cannot be struck, from 10 to 20 cc. of the anesthetic solution may be deposited in its vicinity, and anesthesia will generally develop within ten minutes.

2. External popliteal nerve: The external popliteal nerve crosses the fibula from 2 to 3 cm. below the latter's head and may be readily blocked at this point. The nerve is located by palpation with a finger of the free hand and is injected as it slips from beneath the finger, the needle point being passed through previously anesthetized skin. About 5 cc. of a 2 per cent solution of procaine hydrochloride is sufficient.

B shows the technic for garter infiltration. A subcutaneous injection of a solution of procaine hydrochloride which completely encircles the leg is made just below the bend of the knee, thus completing the anesthesia.

Block Anesthesia for Reduction of Fracture of a Long Bone

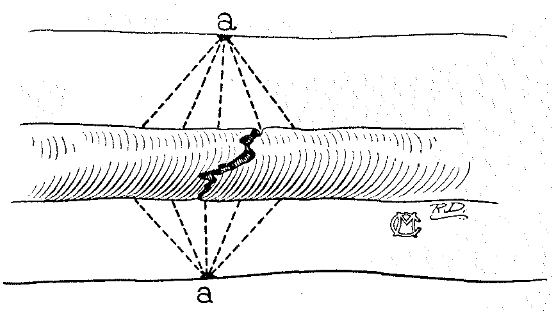

Fig. 66.—Method of obtaining local anesthesia for the treatment of old fractures.

For reduction of a fracture, anesthesia may be produced and relaxation may be obtained by infiltrating the region of the periosteum proximal to the fracture and the soft tissues adjacent to the fracture with a 1 per cent solution of procaine hydrochloride with cobefrin (corbasil) or epinephrine hydrochloride. In many instances, injection into the hematoma of 2½ to 3¾ drachms (10 to 15 cc.) of the solution is sufficient for the purpose. If the line of fracture can be located without too much difficulty, injection between the fragments is advised. Strictest asepsis is necessary.

The anesthesia thus obtained is excellent as a first aid measure preliminary to transportation of the patient to a hospital. It is preferable to inhalation anesthesia if the patient has eaten a meal immediately before suffering the injury. The employment of the method is indicated when the patient's general condition renders undesirable the administration of an anesthetic agent producing general anesthesia.

Lumbar Sympathetic Block

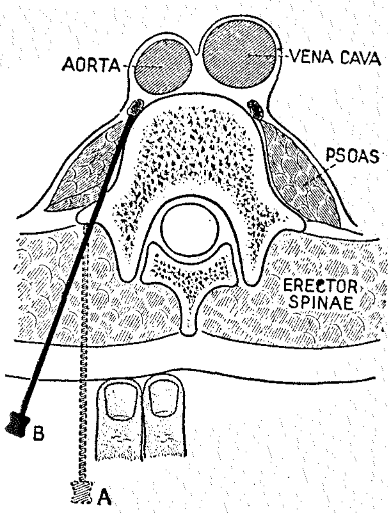

Fig. 67.—Diagram showing the mode of injection of lumbar sympathetic ganglions. The needle is first (*A*) inserted vertical to the skin until it strikes the transverse process, and is then (*B*) withdrawn slightly and slid past the process until it strikes the side of the vertebra, which is the site of injection.

The injection of the lumbar sympathetic ganglions is performed while the patient lies in the lateral position with the thighs and head flexed on the trunk. After the skin over the lumbar vertebrae has been prepared, wheals are made in the skin by intracutaneous injections of a 1 per cent solution of procaine hydrochloride at points approximately 2½ fingerbreadths (5 cm.) lateral to the interspaces of the first, second, third and fourth lumbar vertebrae. These points of the skin lie immediately over the transverse processes of the next vertebrae caudad. A 20 or 22 gage needle 8 to 10 cm. in length is inserted at a right angle to the skin through each wheal until the transverse process of the vertebra is reached, usually a distance of about 4 to 5 cm. (position *A*, fig. 67). The needle is then slightly shifted so that it can project beyond and cephalad to the process and is pointed slightly toward the body of the vertebra. It is now inserted for another 2½ fingerbreadths until its bevel slides off the belly of the vertebra to the anterolateral surface in the retroperitoneal space (position *B*, fig. 67). Through each of the needles 5 cc. of a 1 per cent solution of procaine hydrochloride is injected. Before injection, aspiration should be done in order to avoid the injection of the solution into a blood vessel. Within a few minutes after satisfactory injection, the extremity on that side becomes warm and dry, and the superficial veins become very prominent.

TOPICAL APPLICATION OF ANESTHETIC DRUGS

Topical anesthesia of a mucosal surface or of an area of the skin of the body is useful in many circumstances—for instance, before and during tracheal intubation and before and during bronchoscopic procedures carried out for diagnostic and therapeutic purposes. Most authorities agree that cocaine is the agent of choice for such anesthesia; therefore its use will be emphasized in this section. The recommended strength of the cocaine solution is 1 to 10 per cent. However, for the throat, Magill has recommended a 20 per cent solution, feeling that the greater degree of vasoconstriction obtained permits less absorption and therefore makes this solution safer than less concentrated ones. Other agents (table 6, p. 44) are preferred by some, as substitutes for cocaine. However, some believe those agents more toxic and less effective. *Deaths and toxic reactions are quite as frequent following the topical application of anesthetic drugs as following the injection of these drugs. The reader is referred to page 85 for a consideration of prophylaxis and treatment.*

Pharynx and Larynx

Sprays.—Anesthesia of the mucosa of the pharynx and larynx may be produced by means of a cocaine spray. The atomizer should be of a convenient size to be held in and operated by one hand. This procedure is chiefly useful as a preliminary to tracheal intubation or a bronchoscopic examination. The spray may be introduced into the pharynx and larynx under direct vision with a laryngoscope or it may be applied first to the larynx and vocal cords and then through an endotracheal tube after the latter has been passed into the larynx. The pharynx may also be sprayed by way of the nose while the patient inhales deeply. In a patient whose "gag" reflex is not too sensitive, the application of the anesthetic solution on a cotton swab to each pyramidal fossa is satisfactory. The swab should be squeezed dry of the cocaine solution to prevent drainage of the anesthetic down the esophagus.

Ointments.—For the lubrication of airways and drainage tubes which must remain in contact with mucous surfaces, pastes, jellies or ointments containing cocaine or other agents may be utilized.

Brennan's nupercaine paste is useful for this purpose: paraffin, 1.0; white wax, 2.0; petrolatum, 30.0; nupercaine hydrochloride, 3.3.

Diothane hydrochloride ointment containing diothane hydrochloride in the concentration of 1 per cent has been used as a lubricant for endotracheal tubes.

Troches and Lozenges.—Agents which are effective on mucous membranes may be incorporated in suitable vehicles to dissolve in the normal secretions of the mouth. If the patient holds an anesthetic tablet on the tongue while lying down, the tablet dissolves and the solution gravitates to the base of the tongue, the pharynx and the larynx and may produce sufficient anesthesia to permit the passage of an endotracheal airway. In any case, such a procedure serves as an excellent preliminary for intubation by other aids. Troches containing 5 mg. of pontocaine hydrochloride have been used for this purpose.

Nose

Cocaine sprays or packs will produce satisfactory anesthesia of the lining membrane of the nose. The packs are usually made of absorbent cotton and are inserted with bayonet forceps so that the cotton, from which any excess of solution has been squeezed out, makes contact with the mucous membrane.

Eye

The instillation of a surface anesthetic agent is most frequently applied to the eye. The conjunctival sac will hold 1 or 2 drops of solution at a time. The instillation of a 4 per cent solution of a cocaine salt or the equivalent of another agent needs to be repeated several times in order to obtain the maximal effect.

Urethra

A 2 per cent solution of a cocaine salt may be used for anesthetizing the normal urethra for such procedures as a cystoscopic examination. The amount of solution required is 5 cc., and it should be freshly prepared for each patient. For anesthetizing the most distal portion of the urethra, a small cotton swab is prepared by winding cotton almost the full length of a toothpick and dipping it into a 10 per cent solution of a cocaine salt. After thorough lubrication of the urethra, the swab is fully inserted. With either male or female, ten minutes should be allowed for the anesthetic to take full effect. If the patient's urine is markedly alkaline, a preliminary lavage of the urethra with diluted acetic acid (1:1000) enhances the anesthetic properties of the drug by preventing precipitation of the anesthetic in the solution. In the case of a female patient, 15 cc. of solution may be injected into the bladder with a glass bulb syringe and the urethra plugged with a cotton swab.

Death from the injection of a local anesthetic agent into a traumatized urethra is not uncommon. Urethral stricture or any open, bleeding lesion of the bladder or the urethra contraindicates the use of cocaine. If local anesthesia must be produced in a traumatized urethra, the force with which the agent is injected should be minimal.

RECTUM

One per cent diothane hydrochloride, 5 per cent metycaine or 1 per cent nupercaine in tragacanth jelly have been used for application in painful conditions of the rectum.

DENUDED SURFACES AND OPEN WOUNDS

Various ointments and jellies have been made with local anesthetic agents, such as butyn sulfate, metycaine and intracaine (betadiethylaminoethylparaethoxybenzoate hydrochloride). These agents have been dissolved in petrolatum and in tragacanth jelly. The principal use of ointments, such as 5 per cent metycaine base and white petrolatum, is to allay the pain of open wounds. The latter ointment may be made by precipitating out the base. Such precipitation can be effected by putting a measured quantity of metycaine (which is a mixture of hydrochlorides) in a beaker and covering it with an excess of sodium hydroxide solution. The oily base that appears is the precipitate. The measured amount of white petrolatum should be melted and the base added to it. The mixture should be stirred thoroughly and then allowed to cool. This ointment when applied to open wounds where nerve endings are exposed gives relief almost immediately, and the relief will last for at least twenty hours. Antiseptic agents, especially the vital dyes, may be incorporated in the base without harm to the local anesthetic substance. With such a preparation, wounds may well be dressed so as to relieve pain as well as protect the wound. The need for opiates may thus be obviated or their dosage greatly reduced. The percentages of other local anesthetic agents dissolved in white petrolatum or other vehicle should be comparable to that suggested for metycaine. However, concentrations as low as 2 per cent of metycaine in petrolatum are not satisfactory.

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All the foregoing works except that of Labat are available. Unfortunately, the text by Labat is out of print. Where available, it is an excellent source.

NOTES

VI

Special Technics

CERTAIN OPERATIONS are exceptionally exacting from the anesthetist's point of view, either because of the condition of the patient or because of the nature of the surgical procedure. This chapter is concerned only with technical considerations applicable to anesthesia for such operations. (For anesthetic technics in general, see chapters IV and V.) Several methods far from easy for the novice will be referred to in subsequent pages. It is hoped that the beginner may have the opportunity to perfect his performance of these less familiar technics during administrations to "good risk" patients for simple operations. Thus he may acquire confidence in his ability to perform them with less risk to the patient. For instance, controlled respiration is commonly used with the to and fro carbon dioxide absorption method after intubation. Cyclopropane is often used as an agent for the purpose. It would be ridiculous for the anesthetist who lacked experience with all of these to try to apply any one of them for the first time in a difficult case in one of the groups discussed in this chapter.

For example, the order of mastery might be—

1st	Learn the to and fro absorption technic with nitrous oxide and ether for simple operations on easily anesthetized patients.
2d	Learn to perform intubation under deep ether anesthesia during simple operations when intubation is not essential.
3d	Learn to do controlled respiration with nitrous oxide and ether by the to and fro absorption technic and intubation when the latter procedure is not essential.
4th	Now try to apply the combination of to and fro absorption technic with nitrous oxide and ether and intubation in special cases in which the latter procedure will benefit the surgeon.
5th	Lastly, begin, if you wish, to substitute other agents (cyclopropane, chloroform) for ether.

ANALGESIA BY INHALATION

Analgesia implies obtundation of pain without loss of consciousness. Success or failure in its use depends entirely on the cooperation and mental complacency of the patient.

Certain minor operative procedures do not demand a degree of sensory obtundation necessitating unconsciousness; first stage anesthesia suffices (p. 48). Examples are:

1. Painful dressings.
2. Preparation of a painful dental cavity.
3. Incision and drainage of an abscess.
4. Reduction of a fracture not requiring muscle relaxation.
5. First and often second stage parturition.

Certain patients who are candidates for such operations are of the type who:

1. Undergo a stage of extreme excitement during induction of and recovery from general anesthesia (soldiers recently in action; persons subject to dreams).
2. Cannot safely have local anesthesia because of infections.
3. Can aid the surgeon greatly during operation by their cooperation.

Analgesia may be produced by the inhalation of several agents in concentrations short of those producing second stage effects.

Technic of Pain Relief Without Loss of Consciousness

Mental Preparation of Patient.—Premedication is not necessary.

1. Explain to the patient that he will not lose consciousness, will not feel pain but *will* feel pressure and motion.
2. Check the degree of analgesia with a sharp instrument before the incision is made.

Administration.—(*a*) Self Administration: This is more satisfactory if done with an automatic machine which when pressure is exerted on a hand-operated trigger mechanism (rubber bulb or pistol grip) delivers a fixed quantity of nitrous oxide to be mixed with air in a mask. The patient operates the trigger by both contraction and relaxation of muscles. He judges his own need for gas. He should squeeze the bulb frequently to relieve pain, less frequently to maintain analgesia without unconsciousness. Unconsciousness is reflected in loss of ability to both contract and relax; hence no nitrous oxide is inhaled and there is a return to first stage anesthesia.

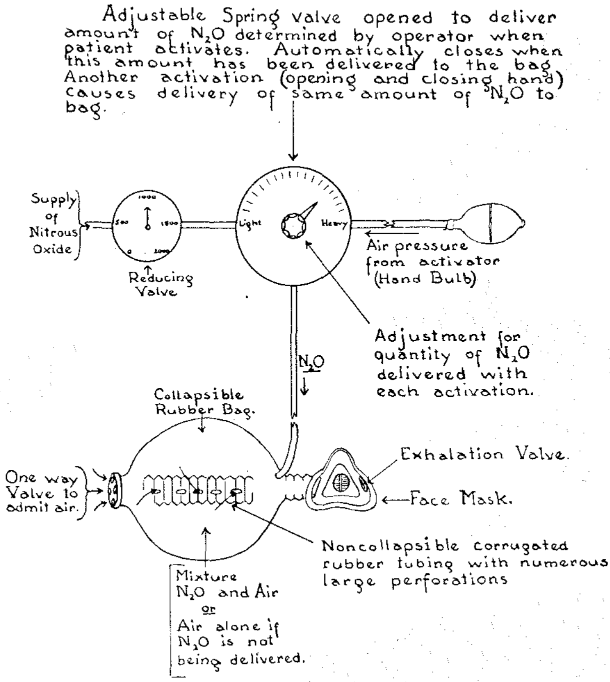

Fig. 68.—Principle of self-controlled nitrous oxide inhalation for analgesia.

(*b*) Administration by Anesthetist:

1. Use nitrous oxide–oxygen (50-50). This is to be administered by an expert only.
2. Maintain constant mental contact with the patient by observing his response to commands to open and close his eyes, raise and lower a hand, or acknowledge the presence or absence of pain.
3. Vary the concentration of each gas according to the response of the patient—increase oxygen when patient does not cooperate; increase nitrous oxide for pain.
4. Avoid the reactionary stage which immediately follows the analgesic stage. (For stages of anesthesia, see p. 48.)

RESPONSIBILITY FOR PRODUCING PAIN RELIEF WHILE MAINTAINING CONSCIOUSNESS MUST BE PLACED ON THE PATIENT, SINCE PHYSICAL SIGNS OF THE FIRST STAGE ARE LACKING.

ANESTHESIA FOR OPERATIONS WITHIN AND ABOUT THE RESPIRATORY TRACT

It is essential that the surgeon and the anesthetist jointly discuss the case and decide what is the wisest way in which to deal with it. The choice of technic and the arrangement of apparatus will vary with each patient. There may be bleeding into the upper respiratory tract. There may be facial defects that complicate induction. Some of these may be painful. The defect may make induction with a mask difficult or impossible because of leakage of the gases. Anatomic defects and abnormalities, as well as recent injuries, may complicate intubation. The operations may be lengthy. Many but not all of these difficulties may be overcome with endotracheal anesthesia (p. 27).

The difficulty encountered by the surgeon in securing satisfactory assistance from the anesthetist for this group of operations has led him in many cases to depend on various technics of local anesthesia administered by himself. The failure of the anesthetist's service in this field is by way of being rectified. In some institutions, the department of anesthesia has been assigned the duty of providing anesthesia for all the specialties concerned with the head. Such a plan should result in a less prejudiced and routine use of anesthetic agents and technics.

Local Anesthesia

Certain *advantages* are evident to the surgeon who himself administers local anesthetics for operations in and about the air passages.

1. He knows intimately the expected extent of the trauma and the demand for anesthesia.
2. He is peculiarly familiar with the anatomy and in a position to place agents properly to produce anesthesia.
3. Cooperation of the patient is retained, permitting clearing the air passages of blood and debris by coughing, blowing and spitting.

The *disadvantages* are:

1. There is inadequate comfort and tranquillity for the patient.
2. Extra time is required for operation.
3. The facilities for the proper accomplishment of some surgical procedures are limited.
4. Interruptions and danger may arise from toxic or undesirable drug effects.
5. The respiratory exchange in a heavily narcotized patient becomes inadequate.
6. The abolition of reflexes of the throat may permit unrecognized contamination of the trachea.

Technical procedures for blocking the various cranial nerves have not been described in this book. References to accepted practices for other nerve blocks will be found on pages 93 to 116, and the technic of topical application of anesthetics to mucous membranes is described on page 117. For management of drug toxicity, see page 85.

Analgesia

By Administration of Nonvolatile Drugs.—Attempts have been made to maintain analgesia by oral or subcutaneous administration of drugs with or without local anesthesia. To guess the dose of a nonvolatile agent which will produce this stage in a given patient is difficult and the result uncertain.

THE ADMINISTRATION OF AGENTS OTHER THAN BY INHALATION FOR OPERATIONS IN AND ABOUT THE UPPER AIR PASSAGES MUST BE ACCOMPANIED BY THE SAME METICULOUS SUPERVISION OF RESPIRATORY FUNCTION (FREE AIRWAY AND VENTILATION) AS FOR SAFETY WITH INHALATION ANESTHESIA.

By Inhalation (see pp. 122 and 123).—The dosage must be governed as to volume solely by the patient's needs as determined by himself, the anesthetist having the responsibility of controlling the concentration of the agent (usually nitrous oxide) in the atmosphere which is under the patient's control. Minor operations, such as the preparation of a tooth cavity, the extraction of a single tooth, the incision and drainage of an abscess, paracentesis tympani and many others, can be done with inhalation analgesia if skilful technic and adequate apparatus are at hand. Either an oral or a nasal inhaler must be used. Temporary or instantaneous periods of third stage anesthesia can be developed from the inhalation technics but involve the risk of second stage complications and had better be avoided.

General Anesthesia

This type of anesthesia may be approached through oral (e. g., barbiturates), hypodermic (e. g., morphine and scopolamine salts), rectal (e. g., avertin with amylene hydrate) or intravenous (e. g., pentothal sodium) administration. The anesthesia is better completed and stabilized by inhalation technics. With few exceptions, third stage anesthesia for major surgical procedures in and about the respiratory tract ought to be accompanied by tracheal intubation (pp. 28 and 29). *Always* the anesthetist must be prepared to intubate at once if need arises during the operation.

By Inhalation.—Induction may present grave mechanical difficulties. If there has been loss of tissue of the face such that an air-tight fit of the mask cannot be obtained, it may be necessary to use a gauze mask and a potent agent, such as chloroform, or to give an intravenous injection of pentothal sodium. If the face is tender to pressure, basal narcosis should precede induction. It may be necessary to remove blood or pus from the pharynx. Intubation of the trachea may be extremely difficult for mechanical reasons: Laryngoscopy may not be possible, because of trismus, or feasible, because of trauma or grafts around the mouth. Wounds may have rendered the nares impassable. Operations of this type call for the services of an anesthetist who is a versatile intubator, skilled in the use of all the routes and methods. If aseptic surgical technic is desirable, it can be only after anesthesia and intubation have been established.

Exceptions.—For certain very brief operations, intubation may be omitted, as in the following examples:

1. Profound third plane anesthesia may be secured by any method and drug and the operation completed during recovery. Drainage and protection of the respiratory tract may be secured by changes in the patient's position or by suction.

2. Nasopharyngeal and oropharyngeal airways have been designed to fit the pharynx in a more or less air-tight manner, thus protecting the lower respiratory tract from contamination. The connection of such an airway with the anesthetic machine does not interfere with some operations in this class.

3. If an oral operation is not prolonged, a nasal inhaler covering a nasopharyngeal airway (p. 26) may serve. Nitrous oxide–oxygen with or without supplement is delivered to the airway under slight positive pressure. A gauze or cotton pack placed across the back of the mouth serves to prevent oral breathing or the aspiration of blood.

4. Certain types of brief operation within the larynx (e. g., the resection of a benign tumor) demand temporary arrest of respiratory movement. For such an operation, the induction of profound third stage anesthesia by an inhalation agent in an oxygen-rich atmosphere, with brief hyperventilation and operation during the following period of apnea, is useful.

5. In the absence of skilled personnel, intubation may be neglected in favor of insufflation of ether or other vapor into the oropharynx via either the nostril or the cheek (p. 74). With this anesthetic technic, the operation had better be done with the patient in a position promoting drainage of blood and other contents of the respiratory passage away from the glottis by gravity. A vigorous use of suction is an added factor of safety.

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AFTER AN OPERATION IN AND ABOUT THE RESPIRATORY TRACT, THE ANESTHETIST MUST ALWAYS HOLD HIMSELF RESPONSIBLE FOR THE CLEANSING OF THE TRACHEA AND BRONCHI (p. 152), INTUBATING ESPECIALLY FOR THAT PURPOSE IF NECESSARY.

ANESTHESIA FOR OPERATIONS WITHIN THE CRANIAL CAVITY

Such operations may be time consuming; the patients often vomit, their reflexes and respirations may be depressed by disorders of the central nervous system, and they are often in awkward positions when operated on, positions in which control of the airway is difficult. If explosive anesthetic agents are used, the frequent use of endothermy must be taken into consideration. On the other hand, there is seldom need for profound narcosis. Some candidates for cerebral operations are already in coma and require no administration of drugs. Relaxation of the muscles is not needed. Stimulation from pain is involved only during the preparation and lifting of the flap. Reflex stimulation occurs, as a rule, only at the base of the brain and near the medulla.

Preparation

Since intracranial pressure may be elevated, any addition of fluids must have the approval of the surgeon and must be discreet. Some drugs are thought to increase intracranial pressure. Opiates are suspected of doing this. Other drugs are believed to lower intracranial pressure. If there is no preference on the part of the surgical team, the anesthetist will probably serve the patient and the surgeon best by "moderation in all things." Moderate doses of the usual premedicant drugs will ordinarily do no harm. If the induction of anesthesia can be accomplished quietly, even with the use of opiates, the disturbance to intracranial pressure may be less than that following a stormy induction. One must remember, however, that the functions of the cranial nerves are frequently disturbed in disease of the central nervous system and that disturbances of function seldom fail to follow intracranial operations. Therefore, drugs that depress reflexes of cranial nerve origin, e. g., the pharyngeal, laryngeal and cough reflexes, must be used cautiously (p. 14 and chap. III). The fact that respiratory depression or arrest frequently occurs before, during and after surgical trauma of the brain is an added reason for carefully individualizing the dosage and the administration of anesthetic drugs.

Administration of Anesthetics

Local.—A thorough field block of the scalp (p. 93) is often adequate. The cases in which local anesthesia is to be used should be chosen with great care and after consultation between the surgeon and the anesthetist. The problem of maintaining a free airway, of controlling uncooperativeness, of instituting artificial respiration and of inducing general anesthesia is complicated dismayingly and sometimes becomes impossible of solution after operation has begun. If the need for such procedures is foreseen by the anesthetist, general anesthesia ought to be provided before the operation is begun.

General.—Light general anesthesia (stage III, plane 1 [p. 48]) is adequate for surgical requirements. However, sufficient obtundation of reflexes to permit tolerance of a pharyngeal or a laryngeal airway and to prevent vomiting is essential. Local anesthetic agents incorporated in lubricants (p. 117) have proved useful for lubricating airways. A cocaine spray has been used for a similar reason and its use repeated during operation. Tribromethanol or this drug in amylene hydrate (avertin with amylene hydrate) has been thought by some to decrease intracranial pressure. At any rate, moderate doses of this agent (up to 100 mg. per kilogram of body weight) by rectum (p. 57) followed with nitrous oxide–oxygen by inhalation through a tracheal airway (pp. 27 and 29) will be found satisfactory. Intubation with administration of ether or chloroform for deep anesthesia offers satisfactory working conditions for the surgeon, as does intravenous administration of pentothal sodium.

The main concerns of the anesthetist must be three:

1. Smooth induction.
2. Free and adequate pulmonary ventilation, without deficiency of oxygen or excess of carbon dioxide, throughout induction and maintenance.
3. Protection of the trachea from contamination with vomitus at the completion of operation and from vomitus and food in

the postoperative period. Do not hesitate to perform suction cleansing whenever indicated (p. 152). Continuous gastric drainage may be necessary.

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NOTES

ANESTHESIA FOR OPERATIONS WITHIN THE PERITONEAL CAVITY

The anesthetist's reputation with his surgeon will be made or marred by his success or failure in producing conditions adequate for the performance with ease of any and all operations within the abdominal cavity. Since the difficulties are more pronounced when operation is to be undertaken in the upper part of this cavity, a detailed consideration of the anesthetic problems of such operations will follow.

The difficulties are dependent on five circumstances: 1. The rectus and transversalis muscles which form the anterior wall of the abdomen are accessory muscles of respiration. Their tone, therefore, tends to persist in planes of third stage anesthesia that are characterized by complete loss of tone in the skeletal muscles of the limbs. 2. The posterior fascial sheath of these muscles is fused with the parietal peritoneum in the upper part of the abdomen. 3. Movements of the primary muscles of respiration (intercostal muscles and diaphragm) in normal breathing cause movements of the abdominal viscera, proportional to the activity of the breathing. 4. Often the condition of the patient or the effect of the drugs causes distention of the hollow viscera. 5. The incidence of postoperative pulmonary complications is high.

The desiderata, then, are: (1) complete abolition of muscle tone in the abdominal wall; (2) prevention of the annoyance to the surgeon resulting from respiratory movements; (3) contraction of the circular muscle fibers of the hollow viscera, "ribbon" intestines; (4) minimum insult to the respiratory mechanism.

Spinal Anesthesia (pp. 44 and 91)

Complete interruption of the nerve supply below the fifth thoracic segment completely abolishes muscle tone from the sixth rib downward and paralyzes the sympathetic system from the superior splanchnic nerve downward.

Desirable Results:

1. Abdominal wall flaccid.
2. Peritoneum lax because the transversus muscle can no longer act on the posterior muscle sheath.
3. Intestines contracted to "ribbons" since the parasympathetic effect is no longer opposed by the sympathetic effect.

Undesirable Results:

1. Occasional failure to point the upper level of anesthesia at the fifth thoracic segment, resulting either in inadequate anesthesia, on the one hand, or in excessive respiratory depression, on the other.
2. Occasional attacks of vomiting or loss of the patient's cooperation. Both events may be secondary to inadequate respiratory exchange, to direct depression of the circulatory system (both on a hypoxic basis) or to traumatic stimulation of parasympathetic nerves—the only ones not paralyzed by adequate spinal anesthesia.
3. Peripheral nerve paralysis, which rarely may follow spinal anesthesia.
4. Postoperative atelectasis of a lower lobe and occasional pneumonia, as with other methods.

Peripheral Nerve Block

A block of the lower seven intercostal nerves in each mid-axillary line (p. 102) or a field block of the abdominal wall (p. 103) serves to make the musculature flaccid but fails of the other two desiderata. A combination of intercostal block, meticulously done, with well conducted general anesthesia at plane 2 of stage III (p. 47) suffices in many instances. The agent for inducing general anesthesia in combination with nerve block is unimportant. The technics should insure that there be no hyperpnea, no coughing, no retching and no respiratory obstruction.

Inhalation Anesthesia

Before the anesthetist can claim recognition, he must be able to produce satisfactory anesthesia by inhalation for work in the upper part of the abdomen. This is a method acceptable even as a last resort when other methods fail.

Ether Administered by the Open Drop Method.—If an adequate airway (pharyngeal, pp. 25 and 26, or laryngeal, p. 27) can be maintained, narcosis at plane 4 of stage III (p. 47) can be secured with ether vaporized on a gauze mask. No other drug is necessary, although some prefer to add, by hypodermic administration, a small amount of an opiate and a member of the atropine group, just sufficient to inhibit secretions. Anesthesia at plane 4 of stage III means respiration maintained by the diaphragm only and that depressed. Oxygen added through a tube under the mask mitigates the damage from hypoxia but does not remove the general tendency toward physiologic disturbances. The determining factor in the choice of this plane of stage III anesthesia will be the speed of operation. Healthy persons tolerate well operations in the upper part of the abdomen lasting for forty-five minutes to one hour. If secretions in the trachea and bronchi are noticed during or at the end of operation, suction cleansing through a tracheal airway (pp. 27-28 and 152) should be repeated until cough and laryngeal reflexes are recovered. A stir-up regimen (p. 152) should follow.

Carbon Dioxide–Ether–Oxygen.—A very few breaths of a mixture of 30 per cent carbon dioxide and 70 per cent oxygen will result in unconsciousness, excessive hyperpnea, extreme abduction of the vocal cords and sensory obtundation of the mucous membranes. If, as soon as consciousness is lost, ether vapor is added to the carbon dioxide–oxygen mixture as rapidly as possible, it will reach the alveoli and blood stream almost instantly. The exhalation valve may be closed during the first few breaths. The rapidity of induction to plane 4 of stage III under these circumstances is largely dependent on the mechanical provision available for rapid vaporization of ether. The induction to profound ether anesthesia must be rapid, since such a high concentration of carbon dioxide may shortly become toxic and depressant as well (pp. 21-22). When induction is well advanced, the exhalation valve may be opened and a semiopen technic with oxygen–ether instituted. Open drop or any other technic may be substituted.

INDUCTION WITH A HIGH CONCENTRATION OF CARBON DIOXIDE IS BOTH DRASTIC AND DANGEROUS. KNOWINGLY USED, HOWEVER, IT MAY BE LESS HAZARDOUS IN THE HANDS OF THE EXPERT THAN THE INSIDIOUS AND UNRECOGNIZED ACCUMULATION OF CARBON DIOXIDE ACCOMPANYING PROLONGED EXCESSIVE REBREATHING IN THE HANDS OF THE NOVICE.

Nitrous Oxide–Oxygen–Ether and Partial Rebreathing (Carbon Dioxide).—Pure nitrous oxide is first added to the mask and to the bag (p. 78), with a minimal flow of oxygen (350 cc. per minute) entering the mask constantly. The exhalation valve is closed temporarily. As unconsciousness appears, begin the addition of ether vapor gradually but progressively, adding more oxygen, either constantly or intermittently, making sure that an adequate supply of oxygen and a good color of the skin are present at all times. The period of relative safety for retention of carbon dioxide in this technic is longer than in the carbon dioxide–ether–oxygen technic, in which carbon dioxide is added from a stock supply. Nevertheless, the signs of severe carbon dioxide toxicity (p. 21) have to be kept in mind and an open technic instituted or the mask removed at the first muscular twitch, which may be the forerunner of a convulsion.

It is obvious that the fast technics of inducing ether anesthesia to plane 4 of stage III are drastic and seldom necessary. They ought to be used only by an anesthetist of long experience and only when he is "in a jam." Nevertheless, it is believed that all anesthetists should know about them.

One more technic for reaching and maintaining the fourth plane of the third stage of ether anesthesia is described in the following section. It is a less drastic though still more radical departure from the beaten path.

Ether and Controlled Respiration.—If the anesthetist is thoroughly familiar with the to and fro carbon dioxide absorption technic (p. 80) and with tracheal intubation (pp. 27-29), he is in a position to secure fourth plane third stage ether anesthesia easily and to maintain it without risk of inadequate ventilation while preventing respiratory movements from interfering with delicate surgical procedures in the upper part of the abdomen.

When ether anesthesia has been established and intubation performed, the breathing bag lying on the pillow at the side of the patient's head is squeezed gently during the latter half of each inspiratory phase of respiration. If the synchronization of this maneuver is perfect and the release of pressure during the expiratory phase is prompt and complete, an augmentation of the depth of the breathing (hyperventilation) will be maintained. This causes the usual result—a lower tension of carbon dioxide that fails to cause impulses initiating contraction of the respiratory muscles. An experienced anesthetist may use this "control of respiration" continuing ventilation by hand. The concentration of ether can now be increased or decreased at will. During delicate surgical maneuvers, the artificial respiratory movements can be timed with the surgical technics so as to cause a minimum of interference—less in fact than that which accompanies the very slight diaphragmatic movement of the lowest plane of third stage anesthesia.

Controlled respiration provides good ventilation in the presence of deep ether anesthesia and opportunity to hold movements in abeyance when necessary in the interest of surgical technic.

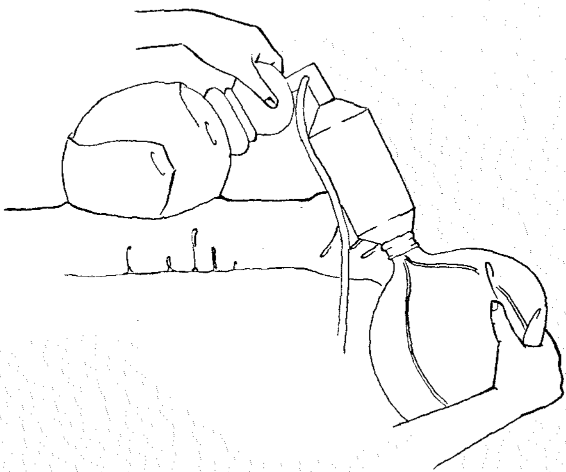

Fig. 69.—Manipulation of the breathing bag.

Dangers

1. Overventilation with resulting depletion of the carbon dioxide or trauma to lung structures.
2. Unrecognized overdosage of ether.
3. Temptation to use to and fro carbon dioxide absorption technic for this purpose before one has acquired familiarity with it by long routine use.

The hyperventilation which keeps normal breathing in abeyance is very slight. The anesthetist should imitate what he believes to be the normal exchange for the particular patient. Occasionally he should interrupt the intermittent compressing of the breathing bag until evidence of beginning contraction of the diaphragm is observed.

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NOTES

REMEMBER THAT ANESTHESIA AT PLANE 4 OF STAGE III IS ACCOMPANIED BY MARKED DEPRESSION OF RESPIRATION AND CIRCULATION. OXYGEN IN THE TISSUES IS LOW AND CARBON DIOXIDE IS IN EXCESS. LIMIT THE TIME OF SUCH ANESTHESIA TO THE PERIOD DURING WHICH IT IS ABSOLUTELY NECESSARY.

THE TECHNICS DESCRIBED FOR SECURING THE FOURTH PLANE OF THE THIRD STAGE OF ETHER ANESTHESIA ARE DRASTIC PROCEDURES DESIGNED FOR USE WITH HYPERSTHENIC PATIENTS. THEY DEMAND EXACTING ATTENTION TO DETAIL. DO NOT EMPLOY THEM WITHOUT SPECIAL INDICATIONS AND THE NECESSARY SKILL TO PERFORM THEM SAFELY.

ANESTHESIA FOR OPERATIONS WITHIN THE PLEURAL CAVITY

PROBLEMS

Three problems are to be held in view: (*a*) pneumothorax; (*b*) contamination of the lungs and air passages; (*c*) mechanical effects on the lungs and air passages, the heart and great vessels and the autonomic nerves.

Pneumothorax.—(Read pages 10 and 153 on normal respiration.) When one of the pleural cavities is opened widely by injury or operation, the negative pressure surrounding the lung is supplanted by atmospheric pressure, the lung collapses and the mediastinum and its contents are sucked toward the opposite side. When the cavity is opened less widely, air rushes in and out of the cavity during the respiratory cycle just as it passes up and down the trachea. At the same time, the mediastinum shifts back and forth with each cycle, disturbing the heart and great vessels. During inspiration some air is sucked from the lung on the open side to the lung on the sound side, thus decreasing by that amount the fresh air entering the sound lung through the trachea (paradoxic respiration). The obvious result will be poorly aerated blood inefficiently transported to the tissues.

It is of interest that with intermittent inflation of the trachea Vesalius (1543) maintained adequate respiratory exchange in the presence of complete bilateral open pneumothorax.

Contamination.—Without pneumothorax, when any part of the lungs or air passages contains secretions, pus or blood, the problem of anesthesia is complicated. A given portion of pulmonary epithelium in constant contact with a foreign substance may become insensitive and the cough reflex worn out. A shift of such substances to an area with more normal mucosa, as from a slight change in breathing or position, may initiate severe coughing. In the presence of open pneumothorax, cough added to paradoxic breathing may serve to spread pus or blood to areas of previously uncontaminated lung. Nosworthy recently referred to this as "vicious circle coughing," the sequence of events being as follows:

> Contaminating material moves to sensitive area of mucosa → cough → ineffective breathing (partly paradoxic, perhaps with obstruction) → dyspnea → more ineffectual breathing → death from asphyxia.

Mechanical Effects.—During operation on the organs in the chest, the lung or a portion of it must be retracted and compressed if adequate working space is made available to the surgeon. The bronchus or the trachea may be occluded by retraction, by torsion or by direct pressure and kinking. In like manner, the great vessels may be constricted or the heart's action embarrassed. The thoracic sympathetic chain on the posterior wall, the vagus nerve and the sympathetic branches in the mediastinum are capable of receiving trauma and stimulating reflexes with results varying from a slight drop in blood pressure and a change in the rhythm of respiration to asystole and apnea.

Preparation for Operation

Patients with Chronic Secretions

1. Postpone operation until sufficiently late in the day to permit the morning "coughing and raising" which is usually characteristic of such patients.
2. Employ postural drainage.
3. Encourage coughing.
4. Resort in some cases to suction drainage through an endotracheal airway or bronchoscope.
5. Produce artificial closed pneumothorax on the diseased side.

Patients with Wounds and Bleeding

1. Keep patient quiet and at rest.
2. Institute oxygen therapy if indicated.
3. Administer a sedative. Sedation may become a part of the anesthetic procedure.
4. Give a blood transfusion if indicated.
5. For patients with bronchocutaneous fistulas, apply an airtight dressing before induction.

Premedication.—Whatever nonvolatile drugs are given previous to the induction of anesthesia and operation, the general principles referred to in chapter III are applicable. Special considerations of importance in dealing with intrapleural operations follow:

1. Autonomic Reflexes: Scopolamine or atropine are known to decrease the activity of the parasympathetic mechanism. Whether the doses of scopolamine hydrobromide or atropine sulfate commonly used (1/300–1/100 grain [0.22–0.65 mg.]) are sufficient protection is doubtful. Probably the surgeon's usual practice of injecting a local anesthetic solution (e. g., 10 to 20 cc. of a 1 or 2 per cent solution of procaine hydrochloride into the tissues of the hilus) preceding trauma to a sensitive region is much more effective.

2. Cough and Expectoration: Stress has already been laid on the importance of the patient's ability to clear the air passages of pus, blood and secretions. When block or spinal anesthesia is used, the patient must be able to cough and expectorate not only before and after but during operation. When general anesthesia induced by inhalation or by intravenous or rectal administration is used, the patient must be able to clear the airways before and after operation. It is important, therefore, that the anesthetist remove the secretions that accumulate during operation.

Present knowledge indicates that all drugs commonly used for premedication tend to depress (*a*) ciliary activity and (*b*) the cough reflex. The use of minimal doses of morphine with minimal doses of scopolamine has found favor with some. Others use larger doses, accurately timed to take effect after the preoperative clearing of the trachea and bronchi. This may prove satisfactory if the effect will have worn off sufficiently at the end of operation to permit coughing and expectoration. The drugs used and the doses chosen will depend on the anesthetist's plan for maintaining anesthesia and on his confidence in his ability to manage bronchial clearance safely.

IN ANESTHESIA FOR INTRAPLEURAL OPERATIONS, THE EFFECTS OF OPEN PNEUMOTHORAX MUST BE MINIMIZED, CONTAMINATING MATERIAL MUST BE CONTROLLED AND STIMULATION OF AUTONOMIC REFLEXES PREVENTED.

PATIENTS WITH AN ABNORMALITY OR AN INJURY OF THORACIC ORGANS ARE COMMONLY IN A CHRONIC STATE OF OXYGEN DEPLETION. THEY ARE PECULIARLY INTOLERANT OF SLIGHT INCREMENTS OF HYPOXIA.

Considerations During Operation

Position.—The accompanying illustration and legend from Nosworthy emphasize the importance of the "head low" position from the standpoint of drainage by gravity when active suction from the trachea and bronchi cannot be depended on. In any case the table should be tilted at an angle of 10 to 20 degrees as a prophylactic measure in view of the possibility of air embolism. If the position for operation is assumed by the patient before the induction of anesthesia is begun, and the effect on respiration and circulation noted, valuable information may be gained.

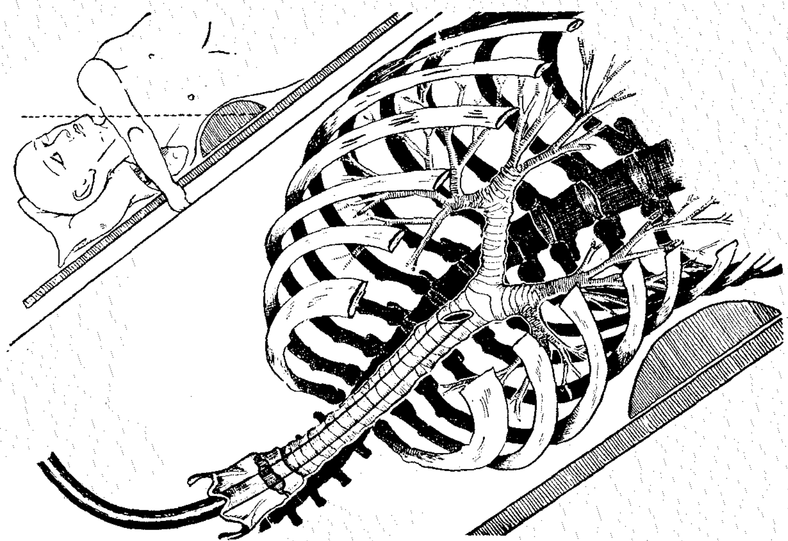

Fig. 70.—Degree of Trendelenburg position necessary to prevent secretion from the left lung running into the right bronchial tree. When the endotracheal tube is not fitted with a balloon, sputum will not be dammed back near the carina.

Anesthesia.—Paravertebral (p. 102) as well as spinal block (p. 91) may serve. Those with the greatest experience, especially in traumatic wounds of the chest, have found general anesthesia preferable for a majority of intrapleural operations. The profound depression (1) weakens the autonomic reflex stimulation from surgical trauma, (2) provides conditions suitable for intubation and either suction clearing of the tracheobronchial tree or intrabronchial isolation of contaminated areas, (3) facilitates the technic of controlled respiration and (4) eliminates the possibility of the patient's coughing during operation with annoyance to the surgeon and possible spread of contamination to noninvolved areas of lung.

The method favored at this time (1942) by anesthetists who have had the greatest experience with anesthesia for intrapleural operations may be outlined as follows:

1. Rapid induction to profound anesthesia without cough or struggling.
2. Early intubation (pp. 27-29).
3. To and fro carbon dioxide absorption technic (p. 80).
4. Controlled respiration (p. 134) during the period of open pneumothorax.
5. Frequent or constant suction drainage of foreign substances from air passages as indicated (p. 152). (Isolation of an area of lung involved by bronchial tamponage and by endobronchial intubation has been tried).
6. Recovery of cough reflex and conscious cooperation as operation is finished.

Those with experience of the technics agree that during maintenance with controlled respiration, the surgical work inside the pleural cavity is made easier, since neither the patient's diaphragm nor his intercostal muscles contract, while the necessary intermittent distention of the lung can be modified to coordinate it with the surgeon's needs. From the anesthetist's standpoint, the open chest provides an excellent guide, not available in abdominal operations, since he may observe directly the extent of the lung's inflation as his hand presses on the breathing bag and thus is assured, on the one hand, of adequate inflation and deflation and, on the other, of protection against overdistention.

Supportive Measures.—A high oxygen tension in the respired atmosphere is desirable during intrapleural operations. Nosworthy very properly calls attention to the importance of carefully recording observations of the circulation. He prefers to start a blood transfusion early (pp. 168-171), maintaining a slow flow until some evidence, such as hemorrhage, indicates the need for an increase in the rate.

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VII

Complications

THE COMPLICATIONS accompanying and following the administration of anesthetic and depressant drugs are many and varied. Their prevention, amelioration and treatment constitute the major effort of the anesthetist. Only training and long experience will prepare him to meet each complication promptly and wisely. In the following pages have been categorically tabulated the steps in the prophylaxis and treatment of many difficulties that may arise. It should be remembered that primarily or secondarily nearly every one of these complications results ultimately in interference with or interruption of the transport system (pp. 9-22)—in other words, in an inadequate supply of oxygen to the tissues and an inadequate riddance of the tissues of carbon dioxide. Consequently, the more thorough the anesthetist's understanding of the physiologic mechanisms of transport (p. 23) and the greater his technical skill in protecting, restoring and maintaining transport, the better service will he render.

Regardless of the complication which may arise, the anesthetist must be prepared to restore instantly (pp. 23-30), and to maintain artificially if necessary (chap. VIII), adequate transport. This is of first importance. Time is thus provided for proper consideration, diagnosis and specific treatment directed at the cause.

The complications listed are not confined to anesthetized patients. Accidents, the weakness of illness, poisoning, drug overdosage, diseases of the nervous system and a host of other causes create a demand for the knowledge and skill of the anesthetist in the medical and accident wards of the hospital, in the street and on the field of battle.

THE ANESTHETIST MUST BE A SKILFUL DIAGNOSTICIAN AS WELL AS A CLEVER TECHNICIAN.

OPERATIVE COMPLICATIONS

Nervousness and Apprehension

Prophylaxis

1. Make a proper psychic approach.
2. Give adequate preliminary sedation.

Treatment

1. Induce anesthesia rapidly with an agent and a method acceptable to the patient.

Coughing

Prophylaxis

1. Encourage the clearance of the air passages before induction.
2. Administer scopolamine or atropine before operation.
3. Increase the concentration of irritating anesthetic gases or vapors slowly.

Treatment

1. Decrease the concentration of anesthetic gases or vapors.
2. Allow the patient to take a few breaths of air.
3. Induce anesthesia rapidly if a nonirritating agent is used.

Vomiting

Prophylaxis

1. Give suitable preliminary sedation.
2. Empty the stomach if possible.
3. Avoid use of an airway until the pharyngeal reflexes are abolished.
4. Pass the vomiting stage quickly.
5. Avoid anoxia.

Treatment

1. Remove the face mask.
2. Wipe or aspirate vomitus from the pharynx and mouth; lower and turn the head to one side.

HEAVY SMOKERS HAVE MUCH TO COUGH UP.

Struggling

Prophylaxis

1. Give adequate preliminary sedation.
2. Arrange for a quiet, undisturbed induction.

Treatment

1. Pass through the stimulatory stage as quickly as possible.

Excessive Mucus

Prophylaxis

1. Give adequate mucus-inhibiting medication (scopolamine or atropine).
2. Smooth induction.
3. Avoid use of an airway until the pharyngeal reflexes are abolished.
4. Avoid sudden changes in the concentration of the anesthetic agent.
5. Avoid too light anesthesia.

Treatment

1. Aspirate from the pharynx.
2. Aspirate from the trachea if necessary.
3. Remove the airway if pharyngeal reflexes are still present.
4. Deeper anesthesia.

Obstructed Airway

Prophylaxis

1. Remove loose dentures.
2. Remove other foreign bodies from the mouth.
3. Support the jaw so the tongue is forward.
4. Bear in mind that allergic patients sometimes have bronchial spasm with some agents, such as cyclopropane.

Treatment

1. Remove any foreign body from the air passages.
2. Move the mandible forward on the maxilla so the tongue does not obstruct.
3. Use a pharyngeal airway.
4. Use an intratracheal airway.

Laryngeal Spasm

Prophylaxis

1. Avoid high concentrations of anesthetic agents during induction and sudden changes during maintenance.
2. Do not allow painful stimulation until the patient has reached the stage of surgical anesthesia.
3. Maintain adequate oxygen tension.
4. Prevent the production of excessive mucus and the accumulation of other foreign material.
5. Spray cocaine on the vocal cords.
6. Do not allow the airway to come in too close contact with the vocal cords.

Treatment

1. Stop operation until the condition has been relieved.
2. Decrease or increase the concentration of the anesthetic mixture.
3. Increase the oxygen tension.
4. Remove excessive mucus from the throat.
5. Avoid excessive carbon dioxide.
6. Increase the pressure on the breathing bag.
7. Inject a solution of an atropine salt intravenously.
8. Use an intratracheal tube.

Respiratory Arrest

Prophylaxis

1. Avoid hyperpnea.
2. Avoid high concentrations of anesthetic agents during induction.
3. Avoid fourth stage anesthesia.
4. Avoid oxygen deprivation.

Treatment

1. Provide a patent airway.
2. Stop administration of anesthetic.
3. Institute artificial respiration with oxygen.

Blood Pressure Fall in Spinal Anesthesia

Treatment

1. Administer oxygen.
2. Inject intravenously a solution of an ephedrine salt or of neo-synephrin hydrochloride.
3. Inject fluids intravenously.
4. Elevate the feet.

Cyanosis

Prophylaxis

1. Administer oxygen in excess.
2. Assure a patent airway.
3. Maintain normal blood pressure.
4. Avoid fourth stage anesthesia.
5. Avoid use of nitrous oxide or ethylene in unsuitable subjects.

Treatment

1. Administer oxygen in excess.
2. Assure a patent airway.
3. Decrease amount of anesthetic.
4. Maintain normal blood pressure.
5. Augment respiration or institute artificial respiration if necessary.

Shock (p. 161)

Prophylaxis

1. Avoid anoxia.
2. Keep patient warm.
3. Avoid excessively abnormal positions.
4. Avoid trauma to tissues (autonomic stimulation).
5. Maintain normal blood pressure by replacing fluid, chloride and blood losses.
6. *Maintain normal intrapleural and intrapulmonary pressures.*

Treatment

1. Administer a high concentration of oxygen.
2. Apply external heat.
3. Inject fluids—preferably blood—intravenously.
4. Elevate the feet.

Autonomic Reflexes (most common are: oculocardiac, carotid sinus, visceral traction and laryngeal [cord spasm])

Prophylaxis

1. Be aware of their existence and possible occurrence.

Treatment

1. Remove the initiating stimulus.

Cardiac Arrhythmia

Prophylaxis

1. Avoid the use of vasoconstrictor drugs in the presence of cyclopropane or chloroform anesthesia.
2. Maintain an excess of oxygen.
3. Avoid sudden changes in the level of anesthesia.
4. Avoid very deep anesthesia.

Treatment

1. Administer oxygen in excess.
2. Lighten the level of anesthesia or change the agent.
3. Institute artificial respiration with oxygen if necessary.

Hypertension and Hypotension Without Changes in Pulse Rate

Prophylaxis

1. They can safely be ignored if not different from the preoperative normal, but hypotension, if prolonged, can cause shock.

Treatment

1. Treat the resulting condition.

Hypertension with Rapid Pulse Rate

Prophylaxis

1. Determine the cause of this definitely unphysiologic state and correct it. Usually it is due directly to oxygen want or to carbon dioxide excess or indirectly to respiratory obstruction or to respiratory depression with inadequate ventilation resulting in oxygen want or carbon dioxide excess.

Treatment

1. Administer oxygen.
2. Provide a patent airway.
3. Increase ventilation.
4. Supply fresh absorber.

Hypotension with Rapid Pulse Rate

Prophylaxis

1. Observe the condition carefully—it is or can become "shock."

Treatment

1. Treat for shock.

Cardiac Arrest

Prophylaxis

1. Avoid profound anesthesia, especially in the elderly and those with cardiac disease.
2. If respiratory arrest or respiratory obstruction occurs, promptly institute artificial respiration with oxygen.
3. Prevent strong stimuli in the presence of light anesthesia.

Treatment

1. Institute artificial respiration with oxygen (high pressure).
2. Massage the heart.
3. Administer analeptics intravenously or intracardially.
4. Use electric stimulation if familiar with the technic.

POSTOPERATIVE COMPLICATIONS

Failure to Recover Consciousness

Prophylaxis

1. Avoid any degree of oxygen want during anesthesia.
2. Be sure the patient has had the proper premedication in the proper dosage.
3. Avoid overdosage of anesthetics.
4. Avoid drugs to which the patient is allergic.

Treatment

1. Administer oxygen.
2. Rule out diabetic coma, insulin shock, increased intracranial pressure, uremic coma, etc.
3. Maintain blood pressure.
4. Give diuretics, such as dextrose, intravenously.
5. Remove mucus from the tracheobronchial tree.
6. Support with stimulants.

Atelectasis (p. 151)

Prophylaxis

1. Be sure there is no foreign material or mucus in the tracheobronchial tree at the end of anesthesia and remove promptly any later accumulations.
2. Encourage the patient to cough.
3. Turn the patient in bed.
4. Encourage the patient to take deep breaths.

   This is the "stir up." Do once per hour.
5. Avoid tight binders.
6. Give carbon dioxide and air inhalations if cooperation of patient in breathing deeply fails.

Treatment

1. Insure coughing every fifteen minutes with conscientious help.
2. Turn in bed frequently (every fifteen minutes).
3. Aspirate the contents of the tracheobronchial tree through an endotracheal tube or a bronchoscope.

Prolonged Vomiting

Prophylaxis

1. Supply adequate oxygen during the anesthesia.
2. Maintain a proper fluid and metabolite balance.

Treatment

1. Administer oxygen.
2. Restore the fluid and metabolite balance.

Postoperative Shock (p. 161)

Prophylaxis

1. Administer oxygen.
2. Maintain blood pressure.
3. Keep the patient warm.
4. Replace the fluid lost.

Treatment

1. Administer oxygen.
2. Elevate the foot of the bed.
3. Inject fluids, preferably blood or plasma, intravenously.
4. Apply external heat.

Parotitis

Prophylaxis

1. Avoid trauma from head straps.
2. Provide chewing gum.
3. Have the patient suck a lemon.

Treatment

1. Nonspecific—apply heat.

Sore Throat

Prophylaxis

1. Avoid injury to the lips and teeth.
2. Avoid trauma from airways, suction tips, laryngoscopes, etc.

Treatment

1. Nonspecific—use warm irrigations.

Ether Burns

Prophylaxis

1. Apply petrolatum around the patient's nares and mouth.
2. Instill bland oil or ophthalmic ointment in the patient's eyes.
3. Cover the patient's eyes with moist cotton.

Treatment

1. Irrigate with water or bland solutions.
2. Instill mild ophthalmic ointment.

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THE GOOD ANESTHETIST OBSERVES THE WHOLE PATIENT, NOT JUST THE HEAD.

VIII

Special Considerations

RESPIRATORY EMERGENCIES

THE ABUNDANT MARGIN of safety maintained by nature for almost every other physiologic function is lacking for the transport of oxygen from the atmosphere to the tissues. Continuous adequate breathing together with adequate blood flow constitutes the transport mechanism. A total failure of either respiration or circulation must be extremely brief if the patient is to survive.

The length of time during which interruption of oxygen transport may be compatible with complete recovery has been the subject of much speculation. It depends on the condition of the cells at the instant of complete interruption of transport and varies from a few seconds to nine or ten minutes. A patient suffering from severe cardiac decompensation may die within fifteen seconds after the initiation of complete respiratory obstruction or after three breaths of pure nitrous oxide. At the other extreme, a healthy athlete after a period during which he breathes pure oxygen may safely stay under water for nine or ten minutes. Recovery of the vegetative functions has been reported following arrests of oxygen transport of considerable duration. The more specialized centers of the central nervous system tolerate want of oxygen poorly. Failure of recovery may be preferable to recovery accompanied with blindness, loss of memory, idiocy or other defects of the higher centers. Methods of resuscitation to be effective must be instituted promptly and must insure efficient transport of oxygen until normal respiratory activity is restored.

Ventilation and Its Maintenance

There are two essentials: First, there must be a free passage between the mouth and nose and the alveolar membrane. This is secured by:

1. Sliding the lower jaw forward on the upper and holding it there, or pulling the tongue out of the mouth (pp. 11 and 24).
2. Using an artificial pharyngeal airway (pp. 25-26).
3. Performing endotracheal intubation (pp. 27-30).
4. Cleansing the lower respiratory tract by the "stir up" regimen and, if necessary, using suction drainage of the bronchial tree to remove any foreign matter which may be obstructing it.

Second, alternate filling and emptying of the lungs must take place in a manner which will assure normal tensions of oxygen and carbon dioxide in the blood and tissues.

Cleansing the Lower Respiratory Tract.—The presence of fluids or foreign substances in the pharynx, trachea or bronchi obstructs respiration and cannot be tolerated. Excessive secretions are seen in healthy patients as the result of irritation of the respiratory mucosa, during thoracic operations or when pulmonary edema occurs. It has been suggested that the use of a constant positive pressure of about 4 mm. of mercury on the respired atmosphere will oppose the tendency to pulmonary edema. Fluids in the pharynx can be removed either by suction or by wiping with gauze swabs. The patient should be prone with the head lowered to assist gravitational drainage and prevent aspiration of foreign matter into the trachea.

(*a*) The Stir Up Regimen: Patients with excessive secretion, those who have aspirated foreign matter or those who are depressed by injury, illness or drugs should be subjected to this routine. Once every hour the nurse or the physician insists that the patient must:

1. Change his position radically or be helped to do so.
2. Cough vigorously.
3. Breathe deeply several times.

(*b*) Tracheobronchial Toilet: If the patient cannot remove fluids in the trachea and bronchi, whether aspirated or originating in the lungs, the condition demands intubation of the glottis (p. 27). With the endotracheal tube in place, a special aspirating catheter or a rubber urethral catheter of size 14-18 French which has been well lubricated is passed down the tube and suction is applied to this catheter, which is moved up and down. The head of the patient or the whole body may be turned from side to side in an attempt to cause the catheter to enter and empty either bronchus. Usually, violent coughing results and this helps to clear the respiratory tree. This procedure can be used in the conscious patient if an effective topical application of cocaine to the pharynx and larynx (p. 117) has been made. If the services of a bronchoscopist are available, he may perform a similar procedure.

Diagnosis and Treatment of Atelectasis.—Following crushing injuries to the chest or after major operations, particularly in the cranial, abdominal or thoracic regions, the anesthetist may have to deal with atelectasis. This complication is usually a sequel to neglect of items *a* and *b* preceding. A bronchus is probably occluded, and the area of the lung concerned collapses as its gaseous content is absorbed.

Physical signs may be noted as follows: There is limitation of movement over the area concerned. Observation in a good light from several angles will usually reveal the asymmetric breathing. Dyspnea is sometimes observed. There is a rise in temperature, pulse rate or respiratory rate. Rarely are palpation, percussion and auscultation of value unless the area of atelectasis is large. Some adventitious sounds may be present. Roentgenograms may confirm the impression of congestion and of cardiac displacement. However, the character of the chest movements, together with the record of the temperature, pulse and respiration, is often sufficient for diagnosis.

Treatment should be instituted at once and repeated often until the chest is clear. Neglect is frequently repaid with pneumonia.

Artificial Respiration.—Normal breathing while at rest is accomplished by intermittent exaggeration of the subatmospheric intrapleural pressure. It is brought about chiefly by synchronous contraction of the intercostal muscles and the diaphragm. Under stress it is probably a combination of active alternate increase and decrease of pleural pressures. When the respiratory muscles cease activity, the lungs are held partly filled at atmospheric pressure by the negative pressure in the pleural cavities in spite of the elasticity of lung tissue which is tending to collapse the lungs and force the contained atmosphere out. To maintain rhythmic exchange of the atmosphere in the alveoli, three physical changes and combinations of these are available: (1) intermittent exaggeration of the negative intrapleural pressure, (2) intermittent increase of the pressure in the alveolar spaces or (3) intermittent decrease of the negative intrapleural pressure.

1. Intermittent Exaggeration of the Negative Intrapleural Pressure. This is brought about by:

(*a*) The Manual Maneuver of Silvester. With the patient in the supine position and a pad under the shoulders, the arms are raised over the head, elevating the ribs, the intrapleural negative pressure is increased, and air rushes into the lungs. When the arms are returned to the sides, the ribs fall, the pleural pressure becomes less negative, and air rushes out of the lungs. Silvester recommended that the arms be pressed against the ribs as they are returned to the sides, to aid in expiration.

(*b*) Mechanical respirators, surrounding the trunk or the whole body below the neck with an air-tight box in which the pressure can be intermittently reduced, thus raising the ribs and the abdominal wall.

2. Intermittent Increase of the Pressure in the Alveolar Spaces. The intermittent transmission of positive pressure to the alveoli through the air passages is accomplished by:

(*a*) Blowing into the mouth or nose (always available).

(*b*) Intermittent direct inflation of the lungs by hand pressure on a rubber breathing bag attached to a face mask or to an artificial airway. It is possible to maintain adequate ventilation satisfactorily in this manner with the chest wall open during or after injury (see p. 135).

These two methods are as efficient and often safer than the numerous mechanical devices, activated by gas pressure, motors, etc., which have been constructed.

3. Intermittent Decrease of the Negative Intrapleural Pressure. The thoracic cage must be made smaller by depressing the ribs or pushing the diaphragm upward, or both. This can be done by:

(*a*) The Schafer prone pressure manual method.

(*b*) Simple intermittent pressure on the ribs or on the abdominal wall.

(*c*) Mechanical devices by which the trunk or part of it is inclosed in an air-tight rigid container and positive pressure is intermittently applied inside the container.

The combinations of principles 1, 2 and 3 are many and varied. Synchronous application of 1 and 2, alternation of 2 and 3 and alternation of 1 and 3 have been advocated.

In general, it may be said that manual maneuvers and direct inflation of the lungs from the operator's own respiratory tract have the advantage of instant availability and intimate personal relation to the effort, *resulting in the likelihood that the rescuer will more readily appreciate defects in the method, such as an obstructed airway and an inadequate or an excessive exchange.* The actual method of performing artificial respiration is relatively immaterial. When the respiratory tract is free of contaminating material, direct inflation of the lungs by blowing intermittently through the patient's mouth or nose is probably the most readily available. The oxygen cylinder, breathing bag and mask ought to be available in hospitals and emergency kits. The Silvester method is as efficient as other manual methods. If the tract is contaminated by foreign material, as after vomiting or drowning, and suction apparatus is not available, the Schafer prone pressure maneuver is safer. The instant application of some method of intermittent exchange when natural effort ceases is all important.

The mechanical apparatus is constructed partially of rubber, which deteriorates, and of intricate machinery, which gets out of order. The anesthetist should inspect such apparatus frequently to learn how it works and how to keep it in repair.

Two factors more important than the method by which exchange is brought about are (*a*) the promptness with which the artificial method is initiated after normal activity has ceased and (*b*) the intelligence and physiologic understanding with which the method is applied.

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OBSTRUCTION AT THE ALVEOLAR MEMBRANE MAY REQUIRE PROLONGED ARTIFICIAL RESPIRATION.

NOTES

INHALATION THERAPY

Supplies and Equipment

Oxygen.—"Medicinal" and "commercial" oxygen are identical, except for the cleanliness of the containers and the price. The oxygen supply of garages for welding and other such purposes is satisfactory for clinical use and is available in almost every community. Efficient reducers and regulators are necessary to bring the dangerously high pressures of cylinder containers within safe limits and to regulate and control the flow of gas to the patient.

Always, before the regulator is attached, open the cylinder valve sharply and briefly. This blows out any particles of dirt which might otherwise enter the regulator and insures that an empty cylinder has not been mistaken for a full one. All valves when not in use should be tightly closed to prevent leaks and loss.

Apparatus.—The apparatus available in different environs varies widely. It behooves the anesthetist when he arrives at a new post to familiarize himself at once with the apparatus provided for the administration of inhalation therapy. If proper equipment is lacking, substitutes for it can usually be improvised if the improvisation is undertaken before the need arises (p. 75). Any machine designed for the administration of gaseous anesthetics can be used for oxygen therapy. A simple assembly of a facial or a nasal mask and a breathing bag serves the purpose. Provision must be made for the elimination of expired carbon dioxide either by discharge through an expiration valve or by chemical absorption in a canister of soda lime (p. 80).

Administration of Oxygen

Indications for oxygen therapy have frequently been mentioned throughout this work. In addition to these, certain medical conditions are treated with high concentrations of oxygen.

Whether the administration of oxygen will be of value to a patient can be determined only by direct experiment. The most reliable physical sign is the pulse rate, but color, breathing (dyspnea), temperature, respiratory rate and blood pressure may also facilitate the decision. Repeated observation of the pulse rate should precede exposure to a high concentration of oxygen; a flow of from 6 to 8 liters per minute is adequate when oropharyngeal methods are in use. The

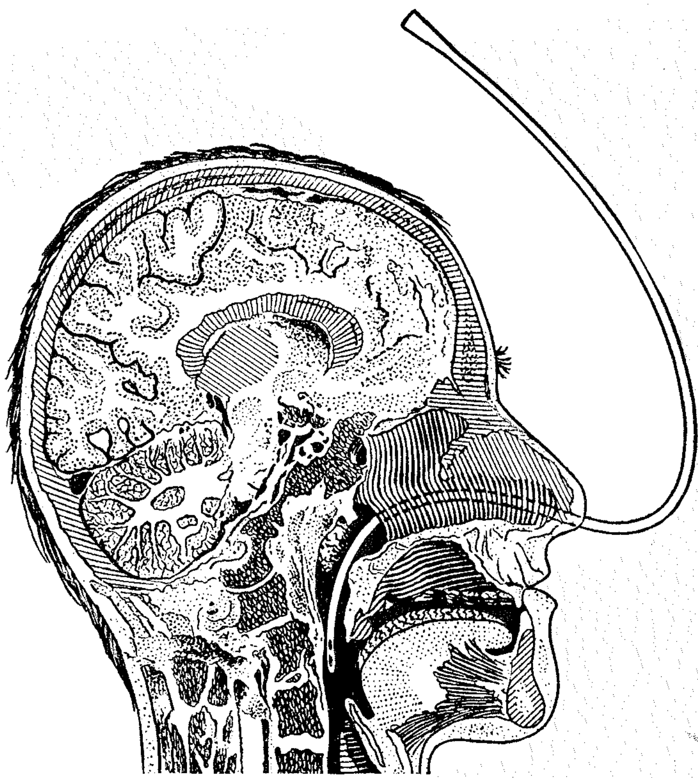

Fig. 71.—The oropharyngeal catheter in place.

maximum fall in pulse rate is noted. This figure then becomes the criterion by which the further administration is regulated. To determine the minimum flow of oxygen which is adequate, reduce the flow by half: If the pulse rate does not rise, a further similar reduction may be undertaken. Should the pulse rate rise after any reduction, the previous higher flow should be restored. By this method, waste of oxygen is eliminated, and the point at which the administration may be discontinued is automatically determined.

The oxygen may be passed through water to moisten it or not, depending on whether the secretions are scanty and dry or plentiful and fluid.

Introduction of Oropharyngeal Catheter.—It is essential that the tip of the catheter be accurately placed in the oropharynx. This tip is first perforated with a number of small holes by running a red hot needle through the terminal one-half inch (1.25 cm.) of the catheter. The proper depth for the catheter can be roughly ascertained by measuring the distance from the ala of the nose to the tragus of the ear. With the oxygen running at 6 liters to the minute, the lubricated catheter is passed into the nose and pharynx until the patient swallows a bolus of oxygen during deglutition. The catheter is then withdrawn to a point at which gas is not swallowed. It is then firmly fastened to the skin of the nose and that of the forehead or cheek with adhesive tape.

At least every twelve hours the catheter should be withdrawn, cleansed and inserted on the opposite side.

Use of an Oxygen Tent.—The patient's head is enclosed by a tent in which the prescribed concentration of oxygen and a comfortable degree of temperature and humidity are maintained. Every oxygen tent is accompanied by a set of instructions issued by the manufacturer, and these should be carefully read and applied. The atmosphere of the tent must be periodically tested to determine the oxygen and the carbon dioxide content.

Use of Carbon Dioxide.—This gas is the normal stimulus to breathing and is sometimes added to inspired atmospheres to stimulate a mildly depressed respiratory center. It should be remembered that concentrations may be reached that stimulate the higher centers, such as the motor cortex, and that concentrations may even become high enough to fail to stimulate, with added depression as a result.

If deeper breathing is desired, the voluntary effort of a conscious, cooperative patient is best. An unconscious or uncooperative patient may be made to hyperventilate if caused to rebreathe from a closed container containing oxygen, the expired carbon dioxide being thus permitted to accumulate. If carbon dioxide from a cylinder is used, the most effective method is to hold the rubber delivery tube so that the gas pours down over the patient's face, enriching the inspired atmosphere. This is continued only until the desired hyperpnea is obtained and then immediately discontinued.

Carbon monoxide poisoning may be effectively treated by allowing the patient to breathe oxygen from a mask and bag with enough carbon dioxide added to produce mild respiratory stimulation. The mask should be equipped with an open exhalation valve, and the flow of oxygen should be adequate to prevent rebreathing.

Use of Helium.—Helium and oxygen mixtures, used under various pressures, are advocated by some as having certain advantages for inhalation therapy. The reader is referred to the current literature for the rationale and technic.

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THE ANESTHETIST SHOULD CONSIDER HIMSELF RESPONSIBLE FOR KEEPING ALL EQUIPMENT FOR INHALATION THERAPY AND RESUSCITATION, AS WELL AS THAT FOR ANESTHESIA, IN WORKING ORDER.

FIRE HAZARD: THERE MUST BE NO SMOKING WHEN OXYGEN IS BEING USED. FOR LEGAL PROTECTION, NOT ONLY MUST ORAL INSTRUCTIONS BE GIVEN BUT WRITTEN WARNINGS MUST BE POSTED.

CIRCULATORY EMERGENCIES

Rapidly developing and extreme depression of that portion of the transport system which depends on the heart and blood vessels usually occurs from one of three causes: (1) mechanical embarrassment, (2) hemorrhage or loss of fluid and (3) disturbances of the autonomic nervous system. In any case the resulting changes in the patient eventuate in a condition ordinarily referred to as SHOCK. Grossly, the diagnosis of shock is made when a patient who has been

PINK WARM AND DRY	Becomes	PALE COLD AND WET

Since it is the anesthetist's responsibility to observe and record the condition of the patient during operation and to direct treatment when this is necessary, he is intensely interested in all prophylactic measures as well as in any reliable means of determining that the patient is undergoing circulatory depression before pallor, cold and wetness appear. For a promising lead in this direction, the appendix to Scudder's book on shock is recommended, as well as an article by Drew (see references, p. 171).

Nevertheless, under the working conditions in the average hospital the anesthetist must be able to correlate cause and effect, usually without aid from the laboratory.

Mechanical Embarrassment

The mechanical causes of circulatory embarrassment are rather obvious and will receive little attention here. If a patient is deficient in vascular tonus or becomes so because of the action of drugs, he obviously lacks the power of compensation for changes in position in which gravity affects the disposition of blood in his body. Again, a tumor within the chest, pericardial effusion, adhesions or other mechanical interference with the filling and emptying of the heart and great vessels may disturb the circulation. The surgeon's manipulations may have a like effect. Finally, changes in the intrapleural pressure resulting from open pneumothorax or from obstruction of air passages may either decrease or increase the pressure surrounding the heart and vessels, thus modifying their effectiveness.

Hemorrhage or Loss of Fluid

Loss of fluid by the anesthetized patient through perspiration or in the expired atmosphere is rarely excessive during the use of the carbon dioxide absorption technic for inhalation anesthesia. Some consider this technic excellent prophylaxis against shock.

When the surgeon's attention is focused on the technical difficulties of the operation, it behooves the anesthetist to watch carefully the amount of blood on the floor and the degree of blood saturation of the accumulated gauze in the floor basin. However, let him not use the loss of blood as an alibi for his own technical shortcomings or a deficiency of knowledge of the fundamentals of anesthesia.

Disturbances of the Autonomic Nervous System

Anesthetic drugs, technical faults in their administration and easily overlooked by-effects of surgical procedure may stimulate or depress in a multitude of ways either of the two components of the autonomic nervous system referred to as the parasympathetic and sympathetic (or the craniosacral and thoracolumbar) nerve mechanisms. To the extent that exact knowledge of the influence of each component on all the organs of the body is lacking, the anesthetist is left to his own resources to determine by clinical observation which of the factors under his control during anesthesia may be causing stimulation or depression of one component or the other, thus decreasing efficient circulation of the blood. The current literature must be watched carefully for any experimental studies contributing to knowledge of autonomic function. The texts of Best and Taylor (see references, p. 22) and Gilman and Goodman (see references, p. 46) have already been suggested as helpful.

Causes.—1. Drugs. It is known that the balance between the two elements of the autonomic system is unstable in certain persons—even though they may appear normal. Hence the effect of drugs on autonomic balance varies widely in different patients. Block anesthesia of one component of the autonomic system permits the other to become dominant. For instance, if a local anesthetic agent is applied only to the sympathetic fibers supplying an organ or area of the body, the blood vessels in that area may lose their power of constriction.

General anesthesia likewise causes depression of autonomic activity, the degree of depression depending on the dose of the anesthetic. There is some evidence that certain drugs have their predominant effect on the craniosacral and others on the thoracolumbar component; e. g., experiments have been reported indicating that some barbituric acid derivatives and ether cause the vascular bed in the spleen to contract while others, as cyclopropane, have no such effect. This or some other similar effect on the autonomic system may explain why it has been suggested that shock after injury may be delayed in its onset for hours if the animal is kept under the profound influence of either barbiturates or ether. While learning all he can of the effects of drugs on the autonomic system from a practical point of view, the anesthetist must still depend largely on clinical experience in his choice of drugs best suited to prevent shock rather than on pharmacologic knowledge. *Varying the depth of anesthesia during a particular operation, sometimes upward and sometimes downward, will often prove of greater value in preventing shock than will a change of agent.*

2. Position. Certain persons, possessed of some abnormality of autonomic balance, may be thrown into a state of circulatory depression solely by sudden changes in position. Others, normal when unanesthetized, may respond in an exaggerated manner when subjected to marked changes in their gravitational relations.

Changes in the position of deeply anesthetized patients had better be made gradually. Avoid extremes.

Positions required for certain operations may themselves directly affect elements of the autonomic system. The "kidney lift" and the "gallbladder lift" are examples. The prone position may embarrass the respiratory exchange; in addition it sometimes has an apparent effect on the neurologic control of circulation.

3. Trauma. Direct trauma to the anatomic constituents of the autonomic system by operation or by injury can cause reflex effects on the circulation, ranging from a giddy feeling in a conscious person to asystole in a completely anesthetized one. Stimuli may pass through such reflexes as the oculocardiac or the carotid sinus reflex. A sudden circulatory effect originates from trauma to the mediastinum, to the thoracolumbar chain, to the portal region of the upper part of the abdomen or to the genitalia.

If the correlation of blood pressure, pulse and respiratory changes with trauma indicates that an autonomic stimulus is the cause of the circulatory depression, the anesthetist's duty is to warn the surgeon and possibly to change the plane of anesthesia. If an accident or an injury is the cause, anesthesia or drug sedation may be indicated.

4. Faults of Anesthetic Technic. The systemic effect of the local use of anesthetic drugs has been discussed in the chapter entitled "Local Anesthesia" (pp. 85 and 88). Often the injection or topical application of these drugs may serve to block stimuli to the autonomic system from trauma during general anesthesia (p. 139). On the other hand, operating under local anesthesia in some regions of the body may, if the anesthetic injection has not caused a complete block, result in autonomic insult, as well as pain, and circulatory depression may result.

The effects of general anesthesia on the autonomic nervous system are many and varied. Exact knowledge of their occurrence is lacking, although further evidence appears in the current literature nearly every month. Under these circumstances the clinical anesthetist when he encounters circulatory emergencies or depressions of circulation of obscure origin during anesthesia will do well to view with suspicion both his drugs and his technic.

Constant palpation of the pulse should be maintained with the ring finger lying over the facial artery. This can be done handily, when a mask is in use, by the hand that holds the mask. *Frequent estimations should be made of the systolic* *and the diastolic blood pressure.* A record of these observations should be kept. Without information accumulated before an emergency has arisen, the frequently insidious onset of circulatory depression will not be recognized.

The anesthetist should familiarize himself with the changes which are more or less unavoidable and routinely characteristic of each drug and technic used in the induction of anesthesia. These changes are usually seen during the early moments of administration. As maintenance and operation progress, the pulse and blood pressure, as a rule, become stabilized.

Whenever during the progress of the operation the rhythm force or the rate of the pulse changes or the blood pressure relations are altered, there is a reason for the change. Find it! The possible technical errors which may lead to circulatory derangement are many. Several will be mentioned.

(*a*) Overdosage. Ventricular fibrillation has resulted from the use of chloroform and cyclopropane. Formerly it was thought to occur when the degree of narcosis was inadequate to prevent stimulation of the autonomic nervous system. Recent evidence points to the probability that ventricular tachycardia followed by fibrillation occurs with extreme dosages.

Overdosage with *ether* results in respiratory depression. The ensuing deprivation of oxygen leads to acute circulatory emergencies. Under such circumstances the vascular tone may be abolished and the cardiac output affected. Extremely low blood pressures result, often accompanied by an increasing pulse rate; in other words, a shocklike picture obtains. If the overdosage of ether has been long continued, *the atmosphere may be enriched with oxygen, or artificial respiratory exchange may be instituted.*

If there has been an overdose of nitrous oxide or of ethylene, the effect on the circulation is likewise that of oxygen deficiency.

(*b*) Excessive Rebreathing. Excessive rebreathing of anesthetic atmosphere may result in the building up of carbon dioxide in the tissues. Oxygen deprivation may or may not occur, depending on the oxygen content of the respired atmospheres. Most types of anesthetic apparatus cause some rebreathing. Such respiratory acidosis requires biochemical adjustment of the organism, a need which may be successfully met at the time. However, in the biochemically handicapped patient the readjustment to normal atmospheric conditions may result in a state of extreme circulatory depression during the period of recovery. The exact mechanism of this reaction is not understood.

(*c*) Respiratory Obstruction. Finally, respiratory obstruction—the commonest technical error—results in respiratory acidosis and oxygen deprivation plus pressure disturbances within the chest cavity. These three factors singly or together have the gravest effects on cardiac output, vascular tone and autonomic balance. A short bout of severe respiratory obstruction or a longer experience with slight obstruction during anesthesia in a susceptible patient may result in shock.

Having considered the causes and common events which lead to deficient circulation and shock, and some immediate precautions that should be borne in mind, the question of what to do about it may be conveniently answered in outline.

Prophylaxis.—In the preoperative period:

1. Avoid restricting the intake of food or fluid without reason.
2. Treat pain and worry adequately.
3. Restore deficiencies due to the patient's condition—electrolytes, dextrose, oxygen.

During operation:

1. Insure that the pain relief is adequate for the particular operation.
2. Maintain adequate respiratory function—no respiratory obstruction; no respiratory depression unless compensated for.
3. Cooperate with the surgeon in promoting the best surgical technic.
4. Recognize and prevent, if possible, stimuli which derange autonomic function.

Treatment.—The patient who is pale, cold and wet demands treatment, sometimes immediate and drastic.

1. If the cause is still active, remove it.
2. Provide an oxygen-rich atmosphere up to 100 per cent, with artificial aid to respiratory exchange if indicated.
3. Insure a free airway (pp. 23-30).
4. Have the head only slightly lower than the heart.
5. Give adequate pain relief (chap. IV).
6. Inject fluids intravenously. (For the technics of venipuncture, see p. 64.)

With respect to intravenous therapy, the following points are important:

(*a*) Proper, chemically pure substances should be procured from a reliable source.

(*b*) Pure, sterile water should be employed, and the water must be from a satisfactory source.

(*c*) The strength of solution to be used depends on the purpose of its administration. Hypotonic or markedly hypertonic solutions generally should not be administered. An exception to this arises when it is desired to obtain the dehydrating effect of a hypertonic solution for a specific purpose.

(*d*) Clean, sterile apparatus should be used and proper precautions should be taken to prevent toxic material from coming in contact with the apparatus.

(*e*) Both the solution and the apparatus should be thoroughly sterilized.

(*f*) The rate of injection should be controlled, since this is important in connection with the proper physiologic compensations. Under ordinary circumstances the injection should not exceed a rate of from 75 to 100 drops per minute. After accidents, as in the presence of active hemorrhage, much faster rates are needed.

The quantity of blood in the body is usually in a definite proportion to the body weight. The weight of blood is approximately 7 per cent, or a fourteenth, of the body weight. This proportion usually holds except in extreme conditions; for instance, (*a*) when a great amount of blood has been lost, (*b*) when marked dehydration is present, (*c*) when the excretory mechanism has failed and fluid has accumulated in the body.

Normally it is difficult to increase or to decrease the volume of the blood for any length of time because of the body's mechanism for interchange of fluid. An excess of fluid is rapidly excreted, and conversely deficiencies of fluid are rapidly compensated for by filtration of fluids from the tissues into the capillary bed. It can be assumed that the blood contains approximately 23 per cent of solids, and the solids of most importance which can be administered parenterally at this time are sodium chloride, dextrose, acacia and the various alkalizing agents which combat acidosis. The solid content of the blood, particularly the saline content, is an important governing factor in the interchange of fluids between the cellular tissues and the blood stream. Intravenous injection of a solution tends to encourage retention of the solution in the blood stream, thereby temporarily increasing the blood volume, particularly if the blood volume is less than normal.

It must not be inferred, however, that maintenance of blood volume is the only indication for intravenous administration of fluid. Under conditions such as circulatory reactions to toxemia, shock and systemic infection, this type of therapy is useful. It can also be used preoperatively and postoperatively to reduce surgical risk and as a supportive measure following surgical procedures.

Fantus has recorded conclusions regarding intravenous administration of dextrose in the course of various clinical conditions substantially as follows:

1. In every instance of a very sick patient one should take care of an adequate income of water, sodium chloride and dextrose as a routine procedure before, rather than after, a high degree of deficiency has occurred.
2. This, when adequate oral administration is impossible, can generally be accomplished best by dextrose phleboclysis, the composition of the solution being determined by the individual indications present.
3. To combat dehydration and for relief of thirst, a 5 per cent solution of dextrose in distilled water seems preferable.
4. Whenever salt starvation is threatened or present, dextrose-saline phleboclysis should be practiced.
5. Whenever carbohydrate cannot be ingested or digested to a sufficient degree, a 10 per cent dextrose phleboclysis should be resorted to.
6. When there is poisoning with a diffusible poison, the diuretic and possible liver-protective action of dextrose phleboclysis adds itself to the foregoing therapeutic values.
7. Concentrated (25 per cent) dextrose solution may be of value in counteracting certain internal hemorrhages, inflammatory and exudative pulmonary edema, and possibly myocardial weakness and in lessening intracranial pressure (unless there is cerebral hemorrhage).
8. During phleboclysis, other remedies may be conveniently infused; e. g., antiserums, epinephrine hydrochloride, insulin, iodides, sedatives and stimulants.

In table 11 are listed various solutions used for intravenous therapy and what is considered the number of cubic centimeters of each solution which may be administered intravenously to the average person with safety.

Blood Transfusion

Landsteiner groups O, A, B and AB are also known as groups 4, 2, 3 and 1, respectively, according to the Moss classification. The latter grouping is probably the most widely used today, but it is not uncommon to utilize both systems for purposes of accuracy and to list the groups as follows: 1(AB), 2(A), 3(B) and 4(O).

The indirect (citrate or other anticoagulant) method of transfusion, on account of its flexibility, is usually preferred to the direct method. The relative incidence of reactions is slightly greater with the indirect method than with the direct method, but the practicability of the latter method is not sufficient to warrant its routine use when a large number of transfusions are performed.

TABLE 11.—*Safe Dosage for the Average Person of Various Substances Used for Intravenous Administration*

Substance	Dose in cc. for Patient of Given Age: 3 Mo. and Younger	6 Mo.	1 Yr.	2 Yr.	5 Yr.	10 Yr.	15 Yr.	20 Yr. and Older	Comment
Blood	75	100	150	200	250	300	400	500	May repeat after 12 hours
Acacia 6%; Sodium chloride 0.9%*; Dextrose 5% in physiologic solution of NaCl; Dextrose 10% in physiologic solution of NaCl; Dextrose 5% in distilled water; Dextrose 10% in distilled water; Hartmann's solution	100	150	200	300	350	500	750	1,000	
Dextrose 20% in distilled water; Sucrose 25%; Sodium bicarbonate, 5%	75	100	150	200	250	300	400	500	Give very slowly
Dextrose 50% in distilled water	..	..	5	10	25	50	75	100	To reduce intracranial pressure

* This is physiologic solution of sodium chloride (NaCl).

To store blood satisfactorily, the icebox or refrigerator must be of reasonable size and one in which the temperature can be controlled so as to prevent freezing. The optimal limit of time for the utilization of stored blood is two weeks or less after the blood has been put in storage, although refrigerated blood three weeks old has been administered to patients without untoward results.

The blood should be tested by at least one of the accepted procedures used in the detection of syphilis.

In the course of many serious operations it may be found advantageous to insert into a vein a needle fitted with a stylet and to anchor the needle securely with adhesive plaster. This maneuver will facilitate intravenous therapy and will obviate the difficulties of venipuncture in sudden circulatory collapse. If necessary, the stylet is removed, the needle and the vein are irrigated with a small quantity of physiologic solution of sodium chloride, and then blood, a solution of acacia or any other desired solution is administered. It is worth while to remember that a solution of acacia should not be administered either before or after administration of blood without first irrigating the tubing, since the acacia may cause clotting of the blood in the tubing or the needle, or even in the vein.

Reactions to Indirect Transfusion.—Among the factors influencing the incidence and number of reactions to transfusions are the rate of administration, the anticoagulant used, the temperature of the blood, the presence of substances to which the patient is allergic and the quantity of blood administered.

The most common signs and symptoms of such a reaction are a rise in temperature, a chill and urticaria; less common are dyspnea and cyanosis.

It has been erroneously assumed that a reaction to a transfusion cannot occur if the patient is anesthetized. It should be emphasized that a reaction may occur even though the patient is under anesthesia. The reaction may not be so obvious as when the patient is not anesthetized, but the symptoms can be detected if the observer is vigilant. It is also a false impression that tetanus antitoxin can be given with impunity when the patient is anesthetized. A reaction may occur also in this instance.

Many agents have been recommended as anticoagulants, such as sodium citrate, sodium oxalate, saline solution, peptone and heparin. Many other agents have been tried, but sodium citrate is still the anticoagulant most commonly used in the indirect method of transfusion.

Serum and Plasma Transfusion

It appears now that either serum or plasma is an effective agent in many conditions in which blood would ordinarily be employed, with the exception of those conditions in which there has been an excessive loss of erythrocytes.

Some advocate serum transfusion rather than plasma transfusion and vice versa. There is no great difference between the two, since plasma is serum plus fibrinogen, thrombin and a diluent in the form of an anticoagulant such as sodium citrate or heparin. Some authors feel that plasma cannot be kept indefinitely because the fibrinogen gradually precipitates out in the form of fibrin veils and a granular precipitate, so that the plasma requires centrifugation or filtration before use. It is argued then that plasma with most or all of the fibrinogen precipitated out is eventually serum plus an anticoagulant.

Whether serum or plasma is used, the supply is limited only by the amount of blood available, and each can be used for many emergencies. Furthermore, serum or plasma transfusions may be administered without the recipient's blood being grouped.

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HEAT CRAMPS, HEAT EXHAUSTION AND SUNSTROKE

Heat Cramps

Cause.—Heat cramps are due to excessive loss of sodium chloride through perspiration.

Symptoms.—The patient presents painful tonic spasms of the muscles of the extremities and abdomen, pallor, moist skin, thirst, a weak but usually not rapid pulse and a temperature at or near normal.

Prophylaxis.—The drinking water should contain 2.5 Gm. of sodium chloride per liter.

Treatment.—Remove the patient to a cool place. Administer opiates for pain if necessary. Give saline solution orally, intravenously or by rectum. Massage affected muscles.

Heat Exhaustion

Cause.—Heat exhaustion is due to excessive loss of sodium chloride and fluid plus a disturbance of the heat-regulating mechanism.

Symptoms.—The patient presents vertigo, pallor, nausea, a weak pulse, rapid respirations, sometimes unconsciousness, a subnormal temperature and moist, cool skin.

Prophylaxis.—Avoid exertion in the hot part of the day—"siesta." Wear loose, light weight clothing. Provide good ventilation. Insure adequate salt intake. Avoid excesses of food and drink.

Treatment.—Administer oxygen, a warm bath and stimulants.

Sunstroke

Cause.—Sunstroke is due to prolonged exposure to high temperatures without adequate dissipation of heat.

Symptoms.—There may be sudden coma. The more usual form comes on with headache, vertigo, unusual disturbances, flushed face, hot skin, high temperature (107-110 F.), labored respirations and convulsions.

Prophylaxis.—Use the same measures as for heat exhaustion plus cold baths, wetting of head and hair with cold water, and frequent rests during forced marching.

Treatment.—Administer oxygen, with artificial respiration if necessary. Use cold baths, cold packs or ice packs with massage to reduce hyperpyrexia. Give saline solutions orally, intravenously or by rectum.

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CONVULSIONS AND STATES OF EXCITEMENT

Causes

One of the following conditions may underlie a convulsion or state of excitement: epilepsy; injury and hemorrhage involving the motor cortex; brain tumor; cerebrovascular accident; meningitis; encephalitis and other infections; effect of drugs (e. g., procaine, metrazol, strychnine); excess of carbon dioxide or depletion of oxygen during general anesthesia; tetanus; hysteria.

Treatment

This will be resolved into (1) direct attack on the cause, (2) preservation of respiratory function and (3) prevention of respiratory sequelae. Often the cause will be unknown and the sole treatment will be to allay the convulsions and to maintain respiratory function, which may be depressed by drug therapy and often is obstructed because of muscle spasm, excessive secretion and edema.

Procaine Convulsions.—Stop the injection! Give artificial ventilation with an adequate airway, preferably with oxygen. If the convulsion persists, a short-acting barbiturate may be given intravenously.

Convulsion During General Anesthesia.—Such an occurrence is usually due primarily not to the action of the drug but to a technical consideration causing abnormal carbon dioxide or oxygen tensions. These when combined with increased heat in the presence of infection and an acid-base imbalance are prone to produce convulsions. Therefore restore normal oxygen–carbon dioxide values by artificial ventilation if necessary and regulate the temperature. If convulsions persist, buffer solutions given intravenously are of value, as are barbiturates.

Other Convulsions.—Convulsions occur outside the operating room from many causes. Specific treatments may be available.

Aid for Which the Anesthetist May Be Held Responsible

1. Terminate the cause.

   Examples: If a convulsion occurs during the injection of a local agent, interrupt the injection. If it occurs while an inhalation technic is being used, disconnect the apparatus and institute respiration by direct inflation.

2. Support respiratory function.

   Convulsions and the need for excessive doses of anesthetic or sedative drugs to stop the convulsions not infrequently result in a period of exhaustion and extreme depression, with need for:

   (*a*) Inhalation therapy (p. 157).
   (*b*) Intubation (pp. 27-30).
   (*c*) Frequent cleansing of the respiratory tract (p. 152).
   (*d*) Artificial respiration (p. 153).
   (*e*) Prophylaxis against pneumonia (p. 152).

3. Stop the convulsion with a sufficient dose of:

   (*a*) Chloroform or ether by inhalation (pp. 78 and 83).
   (*b*) Ether or avertin with amylene hydrate by rectum (pp. 57-60).
   (*c*) Barbiturates by vein (p. 61).

COMA

Coma is not unlike surgical anesthesia, and many of the methods that are regularly utilized by the anesthetist in the management of anesthetized patients are definitely applicable for the prevention of untoward reactions and for treatment of patients in coma. Like surgical anesthesia, coma may vary in depth regardless of the cause. The pupils tend to be abnormal, and there is no rule as to what abnormality will be present in any particular case. The same is true of the reflexes, which depend largely on the degree of coma.

Causes

Among the conditions responsible for coma are the following: effects of drugs (e. g., anesthetics, alcohol, opiates and barbiturates); carbon monoxide poisoning; trauma; burns; hemorrhage; shock; cerebral vascular accident; brain tumor; meningitis; encephalitis; syphilis of the central nervous system; diabetes; uremia; cardiac complication of pneumonia; epilepsy; heat exhaustion; eclampsia; electrical shock.

Diagnosis

The following characteristic features of the more important causes of coma are of diagnostic importance:

Odor of Breath—an alcoholic odor in alcoholism; an odor of acetone in diabetes or uremia; a smell of illuminating gas in carbon monoxide poisoning.

Color of Skin and Mucous Membranes—hyperemic in sunstroke and alcoholism; cherry red in carbon monoxide poisoning; cyanotic in a cardiac complication of pneumonia and in reactions to drugs; pallid in hemorrhage and heat exhaustion.

Local Signs of Injury—found in epilepsy and in injury to the head.

Temperature—increased in encephalitis, pneumonia and meningitis; decreased in carbon monoxide poisoning, reactions to drugs, diabetes and shock.

Pulse—rapid in diabetes, shock and coma, associated with elevation of temperature.

Vomiting—characteristic of drug effects and of cerebral hemorrhage.

Stiff Neck—present in meningitis and cerebrovascular accident.

Muscle Twitchings—present in carbon monoxide poisoning, drug effects or uremia.

Blood Pressure—increased in cerebrovascular lesions, uremia and eclampsia; decreased in trauma and hemorrhage.

Cerebrospinal Pressure—increased in cerebrovascular accidents, sunstroke, meningitis, trauma, syphilis of the central nervous system; decreased in diabetes; bloody in trauma and cerebrovascular lesions; purulent in meningitis.

Urinary Signs—sugar in diabetes; albumin in eclampsia, uremia or cardiac disease. A test for specific substances, e. g., barbiturates, may be positive.

TREATMENT

1. *Remove the cause.* This is done by hemostasis for hemorrhage; administration of antidotes for poisons; blood transfusion for anemia; injection of insulin for diabetes; gastric lavage; splinting of long bones; surgical intervention in some conditions, e. g., ruptured ectopic pregnancy.

2. *Maintain circulation and nutrition.* Replace defects in blood volume by whole blood transfusion or by intravenous or rectal injection of solutions. (Remember that long-continued coma may demand administration of food, catheterization, etc.)

3. *Maintain respiratory function.* When needed, use:
   (*a*) Artificial airways—pharyngeal or laryngeal (p. 25).
   (*b*) Atmospheres enriched with oxygen.
   (*c*) Artificial aid to respiratory exchange (p. 152).
   Respirators should be synchronized to the patient's respiratory rate.
   (*d*) Frequent cleansing of respiratory passages (p. 152).

4. *Use analeptic drugs.* In those specific instances in which they are known by personal experience to be effective these drugs are useful. However, if the cause of the coma can be interrupted, the maintenance of adequate transport (respiratory and circulatory function) will permit eventual recovery.

IN DEEP COMA, ALWAYS INTUBATE TO PREVENT PULMONARY COMPLICATIONS, TO SUPPLY OXYGEN AND TO FACILITATE CLEANSING OF BRONCHIAL SECRETIONS.

POISONING

General Considerations

Numerous drugs cause reactions which at times may embarrass or puzzle the anesthetist before or during the induction of anesthesia.

Scarlet Fever-like Rashes With or Without Fever and Tachycardia.—Prominent among these is the rash or flushing of the skin of the face and neck which so often follows administration of drugs of the atropine group. When such reactions are accompanied by a fast pulse and fever, as they often are, a problem of differential diagnosis presents itself, since it is undesirable to operate on a patient in the early stages of an exanthematous disease, whereas a simple drug reaction is of little moment.

Cyanosis.—Some of the coal tar products, silver in cases of chronic poisoning with this element, and sulfanilamide and its derivatives not infrequently produce blood or skin changes suggesting cyanosis. No proof exists that in patients thus affected there is any inability to transport and deliver oxygen to the tissues. However, their cyanotic skin when they come to be anesthetized is a constant annoyance to the anesthetist and may indicate a possible source of danger.

Leukocytosis.—It should be remembered that the administration of any inhalation agent may be followed by leukocytosis lasting from four hours to several days. This reaction has caused uncertainty in the diagnosis of infections following anesthesia and operation.

Many cases of poisoning result in disturbances of respiration and circulation. Since the anesthetist's training prepares him for the care of these conditions, it is important that he be familiar with the differential diagnosis of poisoning and with the emergency treatment of poisoned patients. Certain considerations are appended, with a hope that they may prove useful.

REMEMBER THAT THE ADMINISTRATION OF APOMORPHINE AND OTHER EMETICS MAY BE FOLLOWED BY PROFOUND RESPIRATORY DEPRESSION.

Clinical Signs Suggestive of Poisoning

1. Burns about the mouth. This suggests corrosives.
2. Sudden onset of nausea, vomiting and/or diarrhea, and/or abdominal cramps, following ingestion of food or drink, especially if several persons are affected. This indicates food contaminants. (There may, however, be an organic abdominal condition, such as appendicitis, intestinal obstruction or perforation of a viscus.)
3. Coma. This suggests depressant drugs, such as opiates, barbiturates, alcohols and carbon monoxide. (On the other hand, it may be due to a cerebral lesion, diabetes, insulin shock, uremia, eclampsia or malaria.)
4. Convulsions. These suggest strychnine, depressant drugs, alcohol, a local anesthetic agent. (The condition may be epilepsy or tetanus.)
5. Dilated pupils. This indicates atropine or scopolamine. (It may indicate a cerebral lesion.)
6. Contracted pupils. This suggests an opiate. (It may be caused by a cerebral lesion.)
7. Slow respiration. This likewise suggests an opiate. (It may be due to uremia or cerebral compression.)
8. Rapid respiration. This suggests atropine, scopolamine, cocaine, opiate (early), carbon monoxide. (It may be associated with a pulmonary or a cerebral lesion or with hysteria.)
9. Cyanosis. This suggests nitrobenzene, potassium chlorate, acetanilid, opiates, carbon monoxide. (It may be due to cardiac, respiratory or cerebral disease.)
10. Paralysis. This accompanies botulism. (It may be caused by a lesion of central nervous system.)

Evacuation

1. Vomiting: If the patient is not too depressed, force fluids by mouth and stimulate vomiting. Emetics that may be used —mustard, apomorphine, ipecac.
2. Lavage by stomach tube: (*a*) avoid injury of the pharynx and contamination of the trachea (pp. 14-15). (*b*) Do not use the procedure when poisoning is with caustic or corrosive drugs, because of the danger of perforation.

Antidotes

1. General: Give milk, egg albumin, activated charcoal or tannic acid. Poisoning, when the cause is unknown, is best treated symptomatically. Support the transport system.

2. Chemical: For the poisonous agents listed below, administer the suggested remedies, many of which form with the poisonous drug an insoluble and inert substance.

   (*a*) Acids—magnesium oxide, solution of calcium hydroxide U. S. P., milk.

   (*b*) Apomorphine—aromatic spirit of ammonia U. S. P.

   (*c*) Arsenic—hydrated iron oxide with magnesia.

   (*d*) Atropine or scopolamine—compound solution of iodine U. S. P. (Lugol's solution), tannic acid, pilocarpine (hydrochloride or nitrate).

   (*e*) Barbiturates—see page 41.

   (*f*) Carbon dioxide—oxygen without rebreathing and artificial respiration.

   (*g*) Carbon monoxide—oxygen without rebreathing and artificial respiration.

   (*h*) Caustic alkalis—vinegar, lactic or citric acid.

   (*i*) Chloroform—oxygen and artificial respiration.

   (*j*) Cocaine—oxygen and artificial respiration, short-acting barbiturate to stop convulsions.

   (*k*) Ether—oxygen and artificial respiration.

   (*l*) Iodine—starch or flour with water.

   (*m*) Mercury bichloride—egg albumin and milk orally, sodium formaldehyde sulfoxylate (5 per cent solution) as lavage and 200 cc. of a 5 per cent solution intravenously slowly.

   (*n*) Methyl alcohol—sodium bicarbonate. Rest. Promote diuresis with intravenous injection of dextrose solution.

   (*o*) Morphine (opiates)—see page 37.

   (*p*) Phosgene gas—see page 184.

   (*q*) Strychnine—charcoal; barbiturate intravenously.

General Therapy

1. Respiratory depression or paralysis:

   (*a*) Use artificial airway (p. 25).

   (*b*) Give inhalations of oxygen (p. 157).

   (*c*) Administer artificial respiration (p. 153).

2. Circulatory depression or failure:

   (*a*) Place patient in head down, feet up position.

   (*b*) Give oxygen inhalations.

   (*c*) Inject fluids intravenously—give blood transfusion.

   (*d*) Apply external heat.

3. Pain: Give opiates.

4. Convulsions (see pp. 173-174):

   (*a*) Give oxygen inhalations.

   (*b*) Inject barbiturates intravenously.

5. Pulmonary edema:

   (*a*) Administer oxygen inhalations with slight positive pressure.

   (*b*) Cleanse bronchi by suction (p. 152).

SPECIAL POISONS

Carbon Monoxide

Carbon monoxide poisoning occurs in military as well as in civilian practice. The gas is colorless, odorless, tasteless, lighter than air.

Source

1. Exhaust fumes from internal combustion motors.
2. Illuminating gas.
3. Combustion of gun powder; explosion of bombs and shells.

Cause

The affinity of carbon monoxide for hemoglobin is 210 times greater than that of oxygen; thus it diminishes the oxygen-carrying capacity of the blood.

Diagnosis

The symptoms depend on the length of exposure, the concentration of the gas and the activity of the victim. In general they are similar to those accompanying deprivation of oxygen under other circumstances.

1. Appearance—skin cherry red or pallid with red blotches; lips blue or purplish; sometimes, a cold sweat.
2. Respiration—rapid, labored and jerky. Later there may be apnea.
3. Circulation—pulse usually slow and strong, later full, rapid and weak; leukocytosis; elevated blood pressure.
4. Central nervous system—headache, drowsiness, vertigo, confusion, loss of memory, possibly convulsions.

After-Effects

Periodic headaches, general weakness, coldness and numbness of hands and feet, pains in chest, palpitation of heart, loss of memory and other psychic changes which may last for variable periods of time. There may be pulmonary sequelae.

Treatment

1. Immediately remove victim from contaminated air.
2. Start oxygen inhalations. Follow with artificial respiration if necessary. Carbon dioxide in 5 per cent or less concentra-

tion may be added to the oxygen. No dead space or rebreathing should be permitted.

3. Provide absolute rest immediately.

4. Later give prophylaxis and treatment of pulmonary complications.

OPIATES (usually morphine, codeine, heroin or laudanum; see pp. 32-37)

Symptoms

1. Respirations—shallow and slow (sometimes falling to 3 to 4 per minute), irregular, stertorous; possibly apnea; sometimes convulsions.

2. Circulation—pulse rapid and full early, later slow and weak; blood pressure elevated early, later falling.

3. Central nervous system—headache, sleepiness, pinpoint pupils, possibly unconsciousness, relaxation of muscles, absence of reflexes, low temperature.

4. Appearance—skin pale, may be cyanotic; cold sweat.

Treatment

1. Give oxygen inhalations (without carbon dioxide).

2. Give artificial respiration (p. 153). A mechanical respirator is desirable.

3. Apply external heat.

4. Wash out stomach if ingestion was recent.

BARBITURATES (see pp. 38-41)

Symptoms

1. Respiration—slow and quiet at first, then becoming shallow and irregular. Apnea may occur.
2. Circulation—pulse rapid and full at first, later becoming slow and weak; blood pressure elevated, then low.
3. Central nervous system—headache, mental confusion, muscle twitchings, sleep deepening into coma, diminution or absence of reflexes, nystagmus, changing of size of pupils.
4. Appearance—may be cyanotic; may be a skin rash.
5. Temperature—elevated.
6. Anuria.

Treatment

1. Insure adequate breathing, artificial if necessary. Use a pharyngeal or a tracheal airway if necessary (pp. 23-30).
2. Give inhalations of oxygen.
3. Wash out stomach if ingestion was recent.
4. Picrotoxin may be added to intravenous dextrose solutions (table 7, p. 45).

OVERDOSES OF OPIATES, BARBITURATES AND SIMILAR DEPRESSANT DRUGS NEED NEVER BE FATAL IF ADEQUATE RESPIRATORY FUNCTION CAN BE MAINTAINED.

War Gases: Lung Irritants (phosgene, chlorine, chloropicrin)

Immediate Effects

1. Suffocation due to damage to alveolar membrane. This becomes a devitalized semipermeable membrane interfering with oxygen and carbon dioxide exchange and allowing fluids to cross into the lung—edema.
2. With high concentrations, death follows immediately, due to reflex respiratory paralysis.
3. With weak concentrations, an inital irritation occurs, followed by coughing, watering of eyes and constriction of chest.

Late Effects

1. Substernal and epigastric pain with cough.
2. Constriction of chest.
3. Nausea and vomiting.
4. Pulmonary edema. The extent and rapidity of development depend on the amount of gas inhaled and the demand for oxygen.
5. Circulation. The loss of serum causes increased viscosity with reduction in the capillary flow; this increases the load on the heart, with dilatation and failure.

Treatment

1. Immediately remove the victim from the contaminated area.
2. Provide absolute rest.
3. Give oxygen inhalations (no positive pressure, for the lung membrane is fragile).
4. Perform venesection (500-700 cc.).
5. Administer compound tincture of benzoin by inhalation.

War Gases: Vesicants (mustard, lewisite)

Immediate Effects: May be none for the first two to six hours irrespective of concentration of gas.

Late Effects (after two to six hours)

1. Eyes—conjunctivitis, copious secretion of purulent material, pain, lids glued together. Recovery of sight is usually complete.
2. Skin—red, burning and itchy, with formation of blisters.
3. Respiratory tract—inflammation resulting in mucopurulent secretions, exudations and diphtheritic-like membrane formation. Necrotic areas separate, leaving ulcers. Swallowing and speaking are painful; there may be occlusion of glottis. Bronchopneumonia, purulent bronchiolitis or necrosis of lung parenchyma may occur.

Treatment

1. Remove from the contaminated area; divest of outer clothing and equipment.
2. Give inhalations of oxygen and compound tincture of benzoin. Gently insert artificial airway if needed or perform tracheotomy.

4. Wash exposed parts with soap and water, rinse with sodium bicarbonate, follow with sodium bicarbonate as dusting powder.
5. Rest the eyes, protect from light, irrigate with a solution of boric acid or a 2 per cent sodium bicarbonate solution.

LARYNGOSPASM AND ACUTE PAIN FROM INHALATION OF IRRITANTS HAS BEEN RELIEVED BY COPIOUS SPRAYING OF PHARYNX AND LARYNX WITH COCAINE SOLUTION (p. 117).

HAZARDS

The anesthetist should be constantly on his guard against certain human, mechanical, physical and chemical errors which in the past have resulted in injury or death.

Mistakes

In Writing Prescriptions and Measuring Drugs.—Prescriptions for depressant drugs must be carefully and legibly written. Mistakes can easily be made between the signs for ounce (℥) and drachm (ʒ) and between actual quantities. Errors in measurement are best avoided by asking another person to witness and verify the prescription, the drug and the dose measured out.

In Identifying Patient or Site of Operation.—It has happened in the past that the wrong operation has been performed owing to a mistake as to the identity of the patient. The anesthetist should therefore inquire as to the patient's name before beginning the induction of anesthesia. He should always note on his chart the side of the proposed operation, as mistakes have occurred as regards repair of a hernia, removal of an eyeball, a kidney or a limb and operations on other bilateral organs. While it is for the surgeon rather than for the anesthetist to be certain that he operates on the correct limb, the anesthetist, by due vigilance, may be able to forestall a serious error.

In Identifying Liquids, Solids and Gases.—Many mishaps have occurred as the result of using chloroform instead of ether. The former liquid weighs nearly twice as much as the latter, and every person working in an operating room should be familiar with their distinctive odors. It is wise always to smell the content of a bottle or can before using it. Mistakes in identity between oxygen, carbon dioxide and the anesthetic gases have also cost lives. Oxygen, nitrogen and helium are the only gases which can not be recognized by their odor. Such mistakes are the responsibility of the anesthetist, and he must undertake to prevent them even though he delegates to others the task of filling bottles or changing cylinders.

Gases Under Pressure

Visceral Ruptures.—Gases are usually stored in cylinders by compression, the usual pressure in a full cylinder being as high as 2,000 pounds to the square inch. Such a pressure accidentally brought to bear on the patient internally will cause death by rupture of the lungs or of the stomach. Care must therefore be exercised in turning cylinders on and off. A safeguard is the use of valve regulators to reduce the high pressure in the cylinder to a lower working pressure.

Ruptures of Apparatus.—A sudden release of gas at a high pressure can rupture closed pieces of apparatus and give rise to a form of explosion. Breathing tubes and bags and glass-enclosed flowmeters have burst in this way, with flying fragments causing injury.

Explosions.—1. From Contact of Oxygen with Fats or Oils: At a high pressure the oxidative properties of oxygen are enhanced. Fats and oils are oxidized with explosive speed and contacting metal can be melted. Such accidents are often referred to as "oxygen fires" or explosions. They can be avoided by handling oxygen cylinders carefully and by making certain that no oil or grease comes into contact with oxygen or nitrous oxide gas that is under high pressure.

2. From Careless Placing: Cylinders are carefully tested but cannot withstand rough handling or a great increase in the pressure of the contained gas. They must never be placed near the source of heat (see p. 188), which could cause an expansion of their contents. If a cylinder is dropped, it may burst with explosive violence.

3. From Admixture of Ethylene: If ethylene at a high pressure encounters oxygen or nitrous oxide at a high pressure, the mixture may become spontaneously oxidized and a violent explosion result. Machines should be so designed that this accident cannot result.

4. From Carelessness in Refilling: The refilling of empty cylinders from full ones is a dangerous occupation. It should not be practiced by any one who is not an expert in the handling of gases at high pressures.

Accidental Extravenous Injection

Certain drugs in solution when injected into the tissues, particularly in high concentrations, have an irritant and sclerosing effect. Mistaken use of a stock solution intended to be diluted before injection has caused sloughs. Concentrated solutions of sodium chloride, barbiturates and anesthetics intended for local use have caused damage when injected unwittingly. If any extravenous deposition of fluid can be felt or if the patient complains of pain, the injection should be discontinued. Hot packs applied to the part will often obviate any serious consequences. If much fluid has been deposited in the tissues, it is probably wiser to incise and drain the tissues than to allow an extensive slough to occur.

Breaking of Needles

Hollow needles often break at the junction of the shaft and the shoulder when they become rusted or old. For this reason, such a needle should not be completely inserted, so that an end will be available for its extraction should it break. This may occur during an injection through a bony foramen, in close proximity to bone or when the patient suddenly contracts the muscle through which the needle is passing. A broken needle in any part of the body must be recovered at once. The slightest movement of the patient should be prevented if possible. Do not transport the patient. Transportation of the patient to procure roentgen aid in localization or help from a surgeon may cause migration of the fragment and transform a simple procedure into a complicated one. If a surgeon is at hand, ask his aid. If not, do not hesitate to incise the tissue gently at once and remove the fragment while its location is clear in your own mind and before it has migrated.

Ignition of Gases and Vapors

All hydrocarbon derivatives are subject to decomposition by heat, and several burn readily and explode when in suitable mixtures with air, nitrous oxide or oxygen. Examples are benzene, acetone, alcohol, ether and other substances used for the preparation of the area to be operated on, as well as for other cleansing purposes. These substances have been ignited in operating rooms by cauteries, electric sparks, etc., with resultant injuries, fires and death.

The only anesthetic gas which does not explode in the presence of heat or sparks that may occasionally be encountered in the operating room is nitrous oxide. It does, however, support combustion just as does oxygen. Chloroform does not explode violently in contact with flame or spark but does decompose to liberate phosgene, an extremely irritant substance. Ether, vinyl ether (vinethene), ethylene and cyclopropane are always potentially dangerous to the same extent as gasoline and illuminating gas in the home. Their specific gravities (pp. 42 and 43) enable one to know whether they will rise or fall after escaping from a leak or an exhalation valve. All the anesthetic gases and vapors except ethylene are heavier than air.

A certain range of inflammability and explosibility for each agent can be demonstrated with a fixed intensity of heat and a fixed oxygen tension. At first thought, this might be considered dependable information. However, since the concentration in the mask varies during every administration from zero to the maximum anesthetic concentration and since this varying concentration becomes variously decreased as the gas escapes into the room, dependence on avoiding the dangerous range is unreliable. The anesthetic mixed with air is less apt to explode than that mixed with atmospheres of higher oxygen tension. Therefore, tensions of oxygen above 20 per cent in an ignitable mixture are more dangerous if exposed to a source of heat. Remember that nitrous oxide in mixtures has an influence similar to that of oxygen.

Sources of Ignition

1. Surgeon's equipment, including the actual cautery and all electrically operated knives, endoscopes and other surgical devices, x-ray apparatus, lights. Any of these may have faulty connections and an electric arc result either at points designed as switches or at points where wires have broken. Each time a wall plug is inserted or pulled out, an arc is formed.
2. Gas and electric heaters and sterilizers, rheostats, etc.
3. Accumulations of static electricity. All surfaces, floors, blankets and tables, the patient, the personnel—every object in the operating room may bear a static electrical charge. If two objects bearing charges of different potential approach each other, a so-called "jump spark" is apt to occur between two surfaces just before they meet.

The present extreme fear of explosion in operating rooms does not appear to be warranted. It produces a state of mind in operating room personnel not conducive to calm thought and action. The incidence of injury or death from explosion is infinitesimal as compared with the morbidity and mortality following hemorrhage and errors in surgical technic or following disregard of respiratory obstruction or depression in and outside the operating room. The dramatic suddenness of the operating room explosion, not its importance as a factor in mortality statistics, has brought it into the limelight. Ever increasing knowledge and skill in surgical technic is reducing the death rate due to surgical procedure. Similar acquisition of facts and their practical application will reduce the danger of explosion. Various organizations and institutions are engaged in the study of the problems involved in the cause and prevention of explosions in operating rooms. Reports of such researches are adding to present knowledge.

General Precautions

1. Exercise vigilance in the operating room at all times. This applies to the entire personnel.
2. Employ block anesthesia or spinal anesthesia or produce anesthesia with nonvolatile agents when these are suitable.
3. Use the carbon dioxide absorption technic in the administration of inhalation agents. The anesthetist should carefully observe the following routine: (*a*) Touch the patient (palpate the pulse) and the gas machine (test flowmeters) before releasing vapors or gases. (*b*) Bring the mask into contact with the face after it has been connected with the apparatus. (*c*) Allow only a noninflammable mixture to flow until all contacts are made. A low concentration of oxygen might well be used for the first half minute of the administration. (*d*) Use deliberation in all movements. Break and remake connections of the mask with the patient and of parts of the breathing apparatus only when each part is in your own hands. (*e*) Moisten the inside of the mask, breathing tube and breathing bag before use.
4. Use nitrous oxide–oxygen anesthesia when this is suitable. (A slight amount of ether or other hydrocarbon added to nitrous oxide may form a highly explosive mixture.)
5. Install only "explosion-proof" electrical equipment specified by the National Electrical Code for hazardous locations. Have it carefully inspected frequently.
6. Avoid higher concentrations of oxygen than are necessary for the needs of the patient.
7. Scrupulously avoid leaks and spilling both of explosive agents and of oxygen.

These recommended safeguards are recognized as incomplete and further experimental investigation into the problem is now under way. A comprehensive report, "Combustible Anesthetics and Operating Room Explosives," on the hazards of explosion has been issued by the National Fire Protection Association. This report was tentatively adopted by that organization and is subject to change. Until the investigative work is completed, presently recommended safe practices should not be relied on to give absolute protection against explosion.

NOTES

COMFORT AND TRANSPORT OF THE WOUNDED

The knowledge and skill of the anesthetist can be useful to the wounded in the street, in the field and during transportation. It is the anesthetist who is probably the most acutely aware of some of the disadvantages of the relief of pain (respiratory obstruction and depression) as well as of the advantages of comfort.

Comfort

Any person experiencing severe pain must be given some medication or administration for that pain. The medication or administration must be given "right now," i. e., just as soon as the sufferer is seen by any one qualified to appraise the situation. The principles of pain relief and preoperative medication have been discussed (pp. 32, 38, 51). Here a few fundamentals of emergency relief of pain will be presented.

The use of ointments and other dressings containing local anesthetic agents has much to commend it (see under "Topical Application," p. 117).

Block anesthesia can provide comfort during transport in selected cases (see pp. 85-116). The extensive utilization of this principle offers the possibility of diminishing markedly the need for injection of opiates.

Morphine is probably the most convenient and reliable agent for injection. In the presence of a large number of casualties the preparation of single hypodermic injections of morphine is a nuisance and a waste of time. In such an emergency a stock solution may be prepared consisting of 16 grains (1 Gm.) of morphine to 1 ounce (31 cc.) of distilled water (Magendie's solution). With this solution in a large syringe and a supply of sterile needles it is possible to administer ½ to ¼ grain (0.03 to 0.016 Gm.) of morphine to thirty-two to sixty-four persons in a short period.

Various barbiturates, such as sodium amytal or soluble pentobarbital in 1½ to 3 grain (0.09 to 0.19 Gm.) doses by mouth or 6 to 9 grains (0.38 to 0.58 Gm.) per rectum (p. 57), are valuable when there is need to relieve mild pain and produce sleep.

The severest of pain, such as that accompanying extensive trauma of sensitive areas (e. g., the genitalia), may require anesthesia for relief. Avertin with amylene hydrate or paraldehyde per rectum (p. 57) will give relief from such pain.

Maintenance of Adequate Respiratory Exchange

The relief of pain by depressant drugs always causes some decrease in respiratory exchange either by depression or by obstruction. The degree of decrease is usually in direct ratio to the amount of drug administered. Respiratory obstruction must be prevented or relieved when present by adjusting the position of the jaw or by providing an artificial airway (pp. 23-30).

The use of an artificial airway in the presence of bleeding wounds about the face or in the mouth requires special attention. A petrolatum pack should be placed about the airway, and the bleeding wound should be packed tightly with gauze to minimize hemorrhage.

A decrease of respiratory exchange due to respiratory depression may be compensated for by the administration of oxygen inhalations, using a cylinder of oxygen, a face mask and a breathing bag (p. 75). In the presence of severe respiratory depression, artificial respiration (p. 153) can be performed effectively by using the same equipment as for oxygen inhalations.

Maintenance of Adequate Circulation

The mechanism of circulation may be disturbed by many factors, such as pain, trauma, want of oxygen, loss of blood, loss of fluid and overdosage of drug. All of these have been considered elsewhere (pp. 161-171). However, it is well to remember that such simple measures as the relief of pain or the restoration of adequate oxygen in the inhaled atmosphere may change an abnormal circulatory condition into a completely normal one.

Low Air Pressure in Airplane Transportation

Some armies are using airplanes for the transportation of the wounded. This presents new problems. The Germans have reported that soldiers with open wounds in their chests do not tolerate airplane flights well. This is no doubt due primarily to the changes in intrapleural pressure due to the wound, which cause respiratory embarrassment, and secondly to the changes of air pressure at altitudes above ground level. Patients with respiratory depression or obstruction would not do well in the air because of the reduced oxygen tension; so additional oxygen must be provided. Likewise, those in shock and those with a reduction of hemoglobin due to loss of blood or other causes would need oxygen by inhalation while in flight. (The use of oxygen for patients suffering from shock or from hemorrhage is discussed on pp. 165-166.)

When necessary, artificial respiration (p. 153) can be performed efficiently in the airplane, ambulance, street, home or hospital with the following equipment:

1. Face mask.
2. Breathing bag.
3. CO_2 absorber (canister). See pp. 80 and 134-135.
4. O_2 cylinder (size D or A).
5. Artificial airways (pp. 23-30).

Appendixes

APPENDIX I

Compressed Gases

Cyclopropane is a gas which liquefies at 75 pounds (34 Kg.) of pressure. It can therefore be marketed in cheap light amplons, which may be discarded when empty.

All other gases used by the anesthetist liquefy at pressures from 750 to 2,000 pounds per square inch (340 to 907 Kg. per 6.5 square centimeters) and must therefore be stored in thick-walled steel cylinders capable of withstanding high pressures.

Table 12 presents the customary pressures of some available gases and the weights and volumes of the contents of the cylinders, and table 13, the weights and sizes of the containers exclusive of their contents.

For convenience and economy, the anesthetic gases may be transported in very large containers.[1] The gases may then be piped to the operating room through brass or copper tubing. High pressure rubber tubing may also be used.

Under certain circumstances the contents of large containers may be transferred to smaller ones. This, however, should be done by those who are expert in handling gases under high pressure. The hospital engineer may assume this responsibility, but under no circumstances should physicians or operating room orderlies assume the task of refilling.

Oxygen is used in large quantities in both the operating rooms and the wards of every hospital. "Commercial Oxygen" is identical with "Medicinal Oxygen" and decidedly less

1. The Australian Expeditionary Forces in Northern Africa have found it expedient to ship large containers to the front, where the engineers' corps assumes the responsibility of transfilling to the small cylinders used on gas machines.

TABLE 12.—*Weights and Volumes of Contents of Cylinders of Some Common Gases Used in Anesthesia, at 760 mm. of Mercury and 0° C.*

Gas		Weight of Content of Cylinder	Volume of Content Cu. Ft.	Gal.
Carbon dioxide	AA	12 oz.	6.2	47
	B	1 lb. 9 oz.	13	97
Usual pressure—	D	3¾ lb.	31	233
835 lb. per sq. in.	E	6½ lb.	54	405
1 oz. = 3.88 gal. = 0.52 cu. ft.	F	20 lb.	166	1,240
	M	31¼ lb.	260	1,940
Color of cylinder*—gray	G	50 lb.	416	3,100
Ethylene	AA	6¼ oz.	5	37
	B	1 lb.	13	96
Usual pressure—	D	2 lb.	25	192
1,250 lb. per sq. in.	E	3⅛ lb.	42	318
	F	11 lb.	140	1,050
1 oz. = 6.0 gal. = 0.8 cu.ft.	M	16 lb.	203	1,570
	G	27½ lb.	352	2,640
Color of cylinder—red	H	30¾ lb.	394	2,960
Cyclopropane	AA	9¼ oz.	4.9	37
	B	1 lb. 7 oz.	12.4	92
Usual pressure—	D	3 lb. 5¼ oz.	28.2	213
75 lb. per sq. in.	E	5 lb. 6¾ lb.	46	344
1 oz. = 4 gal. = 0.53 cu. ft.				
Color of cylinder—orange				
Helium	AA	⅜ oz.	2	15
	B		5.2	39
Usual pressure—	D		9.9	74
1,500 lb. per sq. in.	E		16	112
	F		52	390
Color of cylinder—brown	M		76	570
	G		133	999
	H		175	1,310
Nitrous oxide	AA	12½ oz.	6.5	47
	B	1 lb. 9 oz.	13	97
Usual pressure—	D	3¾ lb.	31	233
800 lb. per sq. in.	E	6½ lb.	54	405
	F	20 lb.	166	1,240
1 oz. = 3.88 gal. = 0.52 cu. ft.	M	31¼ lb.	260	1,940
	G	50 lb.	416	3,100
Color of cylinder—blue	H			
Oxygen	AA	3 oz.	2.1	16
	B	7.25 oz.	5	38
Usual pressure—	D	15 oz.	10.3	79
1,600 to 2,000 lb. per sq. in.	E	1 lb. 8 oz.	16.6	125
	F	5 lb.	55	418
1 oz. = 5.22 gal. = 0.69 cu. ft.	M	8½ lb.	93	700
	G			
Color of cylinder—green	H	17 lb.	186	1,400

* Color Marking for Anesthetic Gas Cylinders, Simplified Practice Recommendation R176-41 United States Department of Commerce, National Bureau of Standards, January 29, 1941.

TABLE 13.—*Weights and Measurements of Cylinder Containers*

	Approximate Weight of Cylinder Exclusive of Contents	Approximate Size of Cylinders
AA	2¾ lb.	3″ × 10″
B	8 lb.	3¼″ × 16″
C		4″ × 18″
D	14 lb.	4¼″ × 20½″
E	21 lb.	4¼″ × 29″
M	70 lb.	7″ × 46″
F	70 lb.	5½″ × 55″
G	110 lb.	8½″ × 55″
H	130 lb.	9″ × 55″

expensive. The delivery of commercial oxygen from large containers to the patients in operating rooms or hospital wards is accomplished in three ways. (The use of oxygen in small containers is rarely justified except for anesthesia.)

1. Large cylinders of oxygen may be transported to the bedside on light trucks. The pressure may be reduced by a combination pressure regulator and flowmeter as the gas is delivered to the patient.
2. Several or many large cylinders may be attached to a manifold with one pressure regulator and an outlet valve set to deliver oxygen at a very low pressure. This is piped—sometimes over long distances—to an outlet in the wall near the patient's bed. In this case a simple valve controls the outlet of oxygen at low pressure, and a simple flowmeter delivers the oxygen to the patient.
3. Oxygen may be delivered in its liquid state in nonsealed "Thermos trucks," similar to those which transport milk. The loss of oxygen by vaporization is not great. Oxygen is pumped from such trucks into a bank of any number of steel cylinders serving merely as storage containers and permanently installed near the hospital. This is known as a "Cascade Unit." From the "Cascade Unit" the oxygen is piped to the patient under low pressure as from the manifold setup described under 2.

Any of these methods of transporting and storing oxygen is a great saving in cost of oxygen and of labor within the hospital. A branch of the pipeline, of course, services the anesthetic machines in the operating rooms.

In figure 72 is shown a mechanism for reducing high pressure in cylinders.

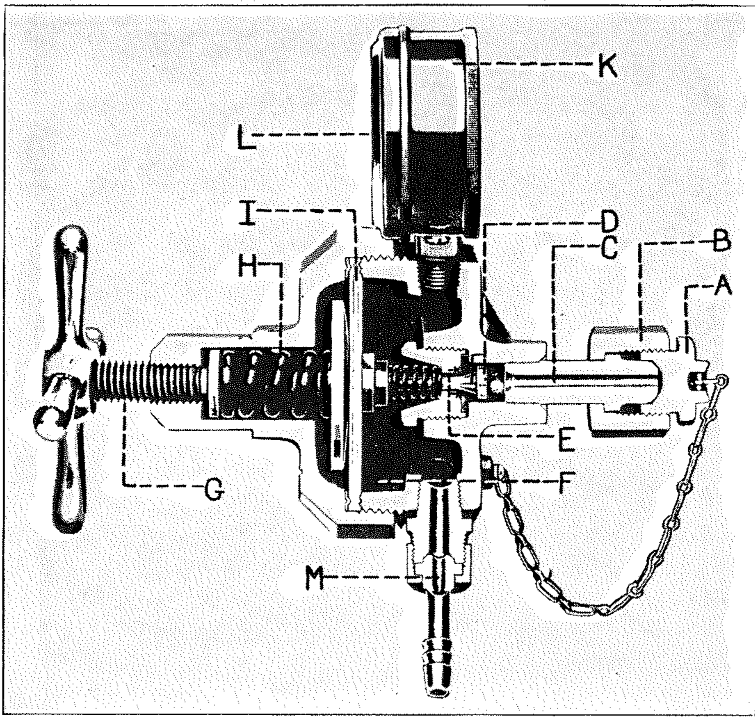

Fig. 72.—Mechanism for reducing high pressure in gas cylinders.

A is a metal plug replacing the cylinder threads when the regulator is not in use, to prevent the entrance of dirt and protect the threads from injury; *B*, a threaded nut for attachment to the gas cylinder; *C*, gas under the same pressure as the cylinder contents; *D*, the conical male element of the valve which high gas pressure forces into the valve seat *E*, preventing escape of gas to the reduced pressure chamber *F*. When screw *G* is advanced against spring *H*, flexible diaphragm *I* transmits force to the male element *D* of the valve, allowing gas to enter chamber *F* until the pressure in *F* is greater than the force exerted on *I* by spring *H;* diaphragm *I* thus releases pressure on *D* and the valve closes. The spring gage *K* registers pressure in chamber *F* on dial *L;* if outlet *M* is small, spring gage *K* can be calibrated to serve as a flow meter and read in cubic centimeters or liters of outflow per minute. An extra spring and hand can be added to the dial of *L*, and connected to *C* so as to register cylinder pressure, or a pressure gage can be added for that purpose.

APPENDIX II

Table 14.—*Table of Equivalents*

Equivalents

1 milligram (mg.)	=	1/64	grain
1 gram (Gm.)	=	15.4	grains
1 kilogram (Kg.)	=	2.2046	lb. avdp.
1 cubic centimeter (cc.)	=	16.2	minims
1 liter (L.)	=	1.05	quart
1 grain	=	.065	Gm.
3/4 grain	=	.048	Gm.
1/2 grain	=	.032	Gm.
1/3 grain	=	.022	Gm.
1/4 grain	=	.016	Gm.
1/6 grain	=	.011	Gm.
1/8 grain	=	8.1	mg.
1/12 grain	=	5.4	mg.
1/16 grain	=	4.0	mg.
1/100 grain	=	.65	mg.
1/150 grain	=	.43	mg.
1/300 grain	=	.22	mg.
1 meter	=	39.37	in.
1 oz. avdp.	=	28.35	Gm.
1 fl. oz.	=	28.35	cc.
1 lb. avdp.	=	453.6	Gm.
1 stone	=	14	lb.
1 inch	=	2.54	cm.

Gas Densities (Wt. of Unit Vol.)

22.4 liters of any gas is equal to its molecular weight in grams at a pressure of 760 mm. of mercury and 0° C.

Molecular Weights

Ethylene	=	28 Gm.
Air	=	29 Gm.
Oxygen	=	32 Gm.
Cyclopropane	=	42 Gm.
Nitrous oxide	=	44 Gm.
Carbon dioxide	=	44 Gm.
Ether	=	74 Gm.
Chloroform	=	119 Gm.

Temperatures

1° Réaumur = 1/80, 1° Centigrade = 1/100, 1° Fahrenheit = 1/180 of the difference between the temperatures of melting ice and boiling water at a pressure of 760 mm. of mercury.

Fahrenheit = (Centigrade × 9/5) +32°
Centigrade = (Fahrenheit —32°) 5/9

Centigrade		Fahrenheit
—18°	=	—0.4°
—10	=	14.0
0	=	32.0
10	=	50.0
20	=	68.0
30	=	86.0
35	=	95.0
36	=	96.8
37	=	98.6
38	=	100.4
39	=	102.2
40	=	104.0
41	=	105.8
42	=	107.6

Solution Equivalents

1 part in 10	=	10.00 %	of which 1 cc. contains	100	mg.
1 part in 50	=	2.00 %	of which 1 cc. contains	20	mg.
1 part in 100	=	1.00 %	of which 1 cc. contains	10	mg.
1 part in 200	=	0.50 %	of which 1 cc. contains	5	mg.
1 part in 500	=	0.20 %	of which 1 cc. contains	2	mg.
1 part in 1,000	=	0.10 %	of which 1 cc. contains	1	mg.
1 part in 1,500	=	0.066%	of which 1 cc. contains	0.66	mg.
1 part in 2,600	=	0.038%	of which 1 cc. contains	0.38	mg.
1 part in 5,000	=	0.02 %	of which 1 cc. contains	0.20	mg.
1 part in 50,000	=	0.002%	of which 1 cc. contains	0.02	mg.

TABLE 15.—*Composition of Normal Urine (A Twenty-Four Hour Specimen, Volume 1,500 Cc.)*

Constituent	Absolute Weight, Gm.	Approximate Per Cent
Water	1,440.0	96.0
Solids	60.0	4.0
Urea	35.0	2.33
Uric acid	0.75	0.05
Creatinine	1.0	0.07
Sodium chloride ($NaCl$)	16.5	1.1
Phosphoric acid (H_3Po_4)	2.5	0.15
Total sulfuric acid (H_2So_4)	2.5	0.15
Potassium (K_2O)	2.5	0.15
Sodium (Na_2O)	5.0	0.3
Calcium (CaO)	0.25	0.015
Magnesium (MgO)	0.30	0.02

TABLE 16.—*Composition of Normal Human Blood*

Constituent	Per Cent
Total solids	19-23
Total proteins (serum)	6.5-8.2
Albumin (serum)	4.6-6.7
Globulin (serum)	1.2-2.3
Hemoglobin	15.6
	Normal Range, Mg. per 100 Cc.
Urea nitrogen	10-15
Uric acid	2-3.5
Dextrose	70-100
Total fatty acids	290-420
Cholesterol	150-190
Lipoid phosphorus (lecithin)	12-14
Carbon dioxide capacity (plasma) volumes per cent	55-75
Chlorides as NaCl	450-500
Sulfates, inorganic as sulfur	0.5-1.0
Phosphorus, inorganic (plasma)	3-4
Calcium (serum)	9-11
Magnesium (serum)	2-3
Sodium (serum)	330
Potassium (serum)	16-22

TABLE 17.—*Comparison of Amounts of Main Constituents of Blood Plasma and Cerebrospinal Fluid* *

	Blood Plasma Mg. per 100 Cc.	Cerebrospinal Fluid Mg. per 100 Cc.
Protein	6,300-8,500	16-38
Amino acids	4.5-9	1.5-3
Creatinine	0.7-2.0	0.45-2.20
Uric acid	2.9-6.9	0.5-2.8
Cholesterol	100-150	Absent
Urea	20-42	5-39
Sugar	70-120	45-80
Chloride (NaCl)	560-630	720-750
Inorganic phosphate	2-5	1.25-2.0
Bicarbonate (volumes per cent CO_2)	40-60	40-60
Hydrogen ions (pH)	7.35-7.40	7.35-7.40
Sodium	325	325
Potassium	20	12-17
Magnesium	1-3	3-3.6
Calcium	9.0-11.5	4.0-7.0
Lactic acid	10-32	8-27

* From Best and Taylor (see references on p. 22).

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