ANESTHESIOLOGY

By FORTY AMERICAN AUTHORS

DONALD E. HALE, M.D., EDITOR

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DONALD E. HALE, A.B., M.D., M.S., F.A.C.S., F.A.C.A.
Supervising Editor
Head of Department of Anesthesiology,
Cleveland Clinic, Cleveland, Ohio

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Foreword

THE purpose and scope of this book is at once obvious when one reviews its subject matter which has been covered by authorities in this wide field of Medicine.

One cannot help but be impressed by the fact that these writers have closed their chapters with a discussion of the safeguards and precautions of some one agent.

Having always been an advocate of simple anesthesia, I think it is well to point out that with the multiplicity of agents we also have a multiplicity of precautions to take in any given case.

It is only fair that surgeons take their share of responsibility for some of the difficulties with which the anesthetists are familiar. In many cases, these difficulties are due, I feel, to unreasonable demands for complete relaxation. These demands may result in complete relaxation, not only of the abdominal wall, but the heart muscle and the cerebral vessels as well.

The real worth of this volume lies in its contribution to safety in anesthesia, and advances in anesthesia cannot be claimed unless morbidity and mortality rates are constantly being lowered.

ROBERT S. DINSMORE,
Chief of Surgery, Cleveland Clinic

DONALD E. HALE, M.D.

Preface

A COMPREHENSIVE volume on the art and practice of anesthesia written by many authors has never before appeared in this country. This volume is in fact a symposium of North American teaching and opinion, since some of the contributors are Canadian. The forty physicians whose work is presented are leaders in the field and are especially qualified to write on the subjects of their respective contributions. The growth of anesthetic knowledge is such that each contributor deals with a specific aspect of anesthesia; this is surely a far cry from anesthesia in its beginnings a century ago; it is nearly as far removed from the anesthetic practice of but very few years back.

The anesthesiologist must have a thorough knowledge of the various surgical needs which he must meet. He must be aware of those conditions which may impose special hazards in some patients. He must be a diagnostician and therapist; his diagnosis must often be instantaneous and must be followed by immediate and accurate therapy. Fluid balance, blood pressure, temperature, respiration, and body position are of importance to him, and these as well as the level of anesthesia he must supervise and modify.

To give anesthesia is not difficult; but to give safe anesthesia is. Light anesthesia that causes the least possible disturbance of normal homeostasis and still fulfills the needs of the surgeon is recognized as most nearly approaching the ideal. The combination of a few agents with which the anesthetist is well experienced serves this end better than the use of many drugs as adjuvants or correctives to the primary agent or agents. There is no agent used by the anesthetist which is not potentially dangerous. The success with which any of these is used depends less on the qualities of the agent itself than on the anesthetist's knowledge of it and his skill in its administration. The contributors throughout stress safety in anesthesia. They emphasize the detection and diagnosis of those conditions, present before or arising during or after operation, which may influence the outcome of both anesthesia and surgery.

This volume should prove of value to anesthesiologists, to surgeons, to general medical practitioners, to medical students, and to those who are in anesthesia training.

I wish to thank the members of the Art, Photographic, and Editorial Departments of the Cleveland Clinic who gave much help in preparing material and proof reading.

The book would not be possible without the high cooperation of the authors who found time in the midst of their busy professional lives to write, rewrite, and twice proof read the material which each contributed.

It would be impossible to give full credit to all those who helped the individual authors in the preparation of their material.

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DONALD E. HALE

Contributors

F. A. DUNCAN ALEXANDER, M.D.
Chief of Anesthesiology, Veterans Administration Hospital, McKinney, Texas.

VIRGINIA APGAR, B.A., M.D.
Professor of Anesthesiology, College of Physicians and Surgeons, Columbia University; Clinical Director, Anesthesia Service, Columbia-Presbyterian Medical Center; New York City, N. Y.

WESLEY BOURNE, M.D., C.M., M.SC., F.R.C.P., D.A. (R.C.P. & S., ENG.), F.A.C.A., F.F.A.R.C.S.
Honorary Anesthetist to the Teaching Hospital of McGill University; formerly Professor of Anesthesia, McGill University; Montreal, Quebec, Canada.

CARLYLE G. BRECKENRIDGE, M.D.
Baylor University College of Medicine; Houston, Texas.

MILTON BROTMAN, M.D.
Senior Assistant Anesthesiologist, Mt. Sinai Hospital; Cleveland, Ohio.

STUART C. CULLEN, M.D.
Professor of Surgery and Chairman of Division of Anesthesiology, University of Iowa; Iowa City, Iowa.

ALBERT FAULCONER, JR., M.S., M.D.
Assistant Professor of Anesthesiology, Assistant Professor of Physiology, University of Minnesota; Consultant in Anesthesiology, Mayo Clinic; Rochester, Minnesota.

RODERICK ANGUS GORDON, C.D., B.SC., M.D., F.R.C.P.(C), D.A.(ENG.), F.A.C.A.
Clinical Teacher in Anesthesia, Faculty of Medicine, University of Toronto; Senior Attending Anesthetist, Toronto General Hospital; Consultant in Anesthesia to Director General of Medical Services, Canadian Army; Toronto, Ontario, Canada.

DONALD E. HALE, A.B., M.D., M.S., F.A.C.S., F.A.C.A.
Head of Department of Anesthesiology, Cleveland Clinic; Cleveland, Ohio.

FREDERICK P. HAUGEN, B.A., M.D.
Professor of Surgery and Head of Division of Anesthesiology, University of Oregon Medical School Hospitals and Clinics; Portland, Oregon.

CURTISS B. HICKCOX, B.S., M.D.
Deputy Chairman, Department of Anesthesiology, Hartford Hospital; Hartford, Connecticut.

ROBERT A. HINGSON, M.D., F.A.C.A., F.I.C.A., F.F.A.R.C.S. (ENG.)
Professor of Anesthesia, Western Reserve University Medical School; Director of Anesthesia, University Hospitals; Cleveland, Ohio.

HEBBEL E. HOFF, M.D., PH.D.
Benjamin F. Hambleton Professor of Physiology, Baylor University College of Medicine; Houston, Texas.

DUNCAN A. HOLADAY, M.D.
Director of Research, Anesthesiology Service, Presbyterian Hospital, Columbia-Presbyterian Medical Center; New York, N. Y.

RALPH T. KNIGHT, M.D.
Director of Division of Anesthesiology, University of Minnesota Hospitals; Director of Anesthesiology and Consultant in Anesthesiology, Minneapolis Veterans Administration Hospital; Head of Department of Anesthesiology, Deaconess Hospital; Minneapolis, Minnesota.

JOSEPH KREISELMAN, M.D.
Assistant Professor of Anesthesiology, College of Physicians and Surgeons, Columbia University; New York City, N. Y.

HUBERTA M. LIVINGSTONE, M.D.
Formerly Associate Professor of Surgery and Director of Anesthesiology, The University of Chicago; Chicago, Illinois.

PAUL H. LORHAN, A.B., M.D.
Professor of Anesthesiology and Chairman, Department of Anesthesiology, University of Kansas Medical Center; Kansas City, Kansas.

JOHN S. LUNDY, B.A., M.D.
Professor of Anesthesiology, Mayo Foundation for Medical Education and Research, Graduate School, University of Minnesota; Senior Consultant in Section on Anesthesiology, Mayo Clinic; Diplomate and Member, American Board of Anesthesiology, Inc.; Rochester, Minnesota.

K. C. MCCARTHY, M.D.
Consultant in Anesthesia, Maumee Valley Hospital; Anesthetist to Flower Hospital, Mercy Hospital, and Toledo State Hospital; Toledo, Ohio.

CHARLES F. MCCUSKEY, M.D.
Professor of Surgery (Anesthesiology), University of Southern California; Los Angeles, California.

NORMAN R. J. MCMILLEN, M.D.
Vancouver, British Columbia, Canada.

LLOYD H. MOUSEL, B.S., M.S., M.D.
Director of Anesthesia, The Swedish Hospital; Seattle, Washington.

MORRIS J. NICHOLSON, M.D.
Member, Department of Anesthesiology, Lahey Clinic; Anesthesiologist, New England Deaconess Hospital; Associate Anesthesiologist, New England Baptist Hospital; Boston, Massachusetts.

BENJAMIN H. ROBBINS, M.S., M.D.
Professor of Anesthesiology, Associate Professor of Pharmacology, Vanderbilt University School of Medicine; Anesthesiologist-in-Chief, Vanderbilt Hospital; Nashville, Tennessee.

D. A. ROMAN, M.D.
Senior Anesthesiologist, St. John's Hospital; Santa Monica, California.

MEYER SAKLAD, M.D.
Director of Anesthesiology, Rhode Island Hospital; Providence, Rhode Island.

BRYANT B. SANKEY, B.S., M.D., F.A.C.A.
Diplomate, American Board of Anesthesiologists; Cleveland, Ohio.

THOMAS H. SELDON, M.D., C.M., M.S. IN ANES.
Associate Professor of Anesthesiology, Graduate School, University of Minnesota; Member, Section on Anesthesiology, Mayo Clinic; Rochester, Minnesota.

HARRY S. SHIELDS, B.A., M.B., F.R.C.P.(CAN.), F.F.A.R.C.S.(ENG.)
Consultant in Anesthesia to the Toronto General Hospital, to the Hospital for Sick Children, and to the Women's College Hospital; Toronto, Ontario, Canada.

C. R. STEPHEN, B.SC., M.D., C.M., D.A., F.A.C.A.
Professor of Anesthesiology, Duke University School of Medicine; Chief of Anesthesia, Duke Hospital; Durham, North Carolina.

RONALD J. M. STEVEN, B.SC., M.B., B.S., D.A. (R.C.P&S.), D.N.B., F.A.C.A.
Diplomate, American Board of Anesthesiology. Associate, Attending Staff, Hartford Hospital; Hartford, Connecticut.

ARTHUR B. TARROW, B.A., M.D., M.S. (ANES.), F.A.C.A.
LIEUTENANT COLONEL, USAF
Clinical Assistant Professor in Anesthesiology, University of Texas Medical School; Chief of Anesthesiology Section and Director of the USAF School of Anesthesiology, 3700th USAF Hospital, Lackland Air Force Base; Diplomate, the American Board of Anesthesiology; San Antonio, Texas.

IVAN B. TAYLOR, M.D.
Clinical Professor of Anesthesiology, Wayne University College of Medicine; Consultant in Anesthesiology at Dearborn Veterans Administration Hospital; Detroit, Michigan.

RALPH M. TOVELL, M.D., M.SC. (ANES.) F.F.A.R.C.S.
Lecturer in Anesthesiology, Yale University School of Medicine; Chairman, Department of Anesthesiology, Hartford Hospital; Hartford, Connecticut.

EDWARD B. TUOHY, B.S., M.D., M.S. (ANES.)
Professor of Surgery (Anesthesiology), University of Southern California Medical School; formerly Professor of Surgery (Anesthesiology), Georgetown University Medical Center, Washington, D. C.; LaCanada, California.

CARL E. WASMUTH, B.S., M.D.
Department of Anesthesiology, Cleveland Clinic; Cleveland, Ohio.

ROLLAND J. WHITACRE, M.D.
Director, Department of Anesthesiology, Huron Road Hospital; Cleveland, Ohio.

JOHN W. WINTER, M.D.
San Antonio, Texas.

PHILIP D. WOODBRIDGE, A.B., M.D.
Chief of Anesthesia, Franklin County Public Hospital; Greenfield, Massachusetts.

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ANESTHESIOLOGY

HEBBEL E. HOFF, M.D., AND CARLYLE G. BRECKENRIDGE, M.D.

1

*Physiology in Anesthesia**

THE surgeon employs anesthesia for three primary reasons: (1) to prevent pain, (2) to calm fears, allay anxiety, and give forgetfulness, and (3) to achieve adequate muscular relaxation. These fundamental goals of anesthesia become the three basic problems of the physiologist studying the operation of anesthetic agents: (a) What is pain and how does anesthesia affect it? (b) What are consciousness and unconsciousness, and how does anesthesia operate in clouding consciousness? (c) What is the physiological mechanism of muscle tone and what are the weak links in the chain of reactions maintaining it that are accessible to anesthesia?

These are the fundamental problems of the physiology of anesthesia, but two more must be added. Classical anesthesia is inhalation anesthesia; in modern anesthesia it is still of great importance. In almost all types of anesthesia attention to respiration is a constant necessity. It is natural then that as anesthesia grew from the respiratory studies of Priestley and Davy, the anesthetist of today should maintain his interest in the physiology of respiration. To the three primary questions can then be added a fourth: How is respiration maintained and regulated, and how does anesthesia influence it?

With the discovery of the anesthetic effects of chloroform, and its introduction into anesthetic practice, it was realized that the cardiovascular system might be primarily damaged by anesthesia, and that patients might die from cardiac failure while the respiratory system still functioned. This opened a new field of physiological inquiry, and the fifth major problem of the physiologist: How are the factors regulating blood pressure influenced by anesthesia?

To answer these five questions to the extent and in the detail that their interest merits and their importance demands would be beyond the scope of this single chapter, which must serve rather as a series of introductory essays.

I. PAIN

Pain is a fundamental human experience woven into the fabric of behavior in health and disease from the physiological to the sociological level. At the physiological level it operates through a specific neurohistological substratum and influences reactions at the spinal, thalamic, and cortical levels. It enters into

* The studies in respiration described here have been supported by grants to Baylor University College of Medicine from the M. D. Anderson Foundation and by a special research grant from Hoffmann-La Roche, Inc., to the Department of Physiology. This section was read to the annual meeting of the American Society of Anesthesiologists at Houston on November 8, 1950.

normal and pathological psychological behavior in ways which have as yet defied neurophysiological analysis, and recent trends in obstetrics illustrate how individual, social, or national attitudes may modify an individual's reaction to it. The anesthetist must necessarily deal with all of these facets of the problem of pain in achieving his primary purpose. He has another responsibility, however. In the phenomenon of pain, physiological and psychological processes come close together, and the anesthetist is in a unique position to study the connections between the two. Anesthesia thus becomes not simply a method of treatment but an important tool in the study of that most important problem, the interpretation of psychological behavior in terms of physiological processes. The anesthetist of the present day has fulfilled superbly his first responsibility. He has barely faced his second.

The Peripheral Neurohistological Basis for Pain; the Pain Unit: We may accept today as fundamentally true the postulate implied in Müller's doctrine of specific nerve energy that pain is mediated by a peripheral fabric of afferent nerve fibers devoted specifically to the reception of stimuli which, translated into impulses, upon reaching the higher levels of the central nervous system are interpreted as pain. In general the stimuli which set off these impulses are those which threaten the integrity of bodily structure, either on the surface, as in the skin or in the cornea, or in the deeper structures of the body, such as muscles, tendons, joints, and viscera. The afferent neurone is the first in the chain of neurones that relay these impulses into the spinal cord and upward to the brain. Just as Sherrington has defined the peripheral organ of muscular activity as the motor unit, consisting of a neurone in the anterior horn of the spinal column with its axon, peripheral divisions, and the muscle fibers which they supply, so the peripheral unit of pain reception can be defined as a dorsal root ganglion cell with its axon reaching out to the periphery of the body where it ramifies terminally and the central projection by which impulses generated peripherally are brought into the spinal cord and relayed to higher levels of the central nervous system.[1,2] Recent histological investigations make it clear that pain is mediated by both myelinated and nonmyelinated fibers which emerge from deeper structures into the skin in company with many other similar fibers and form rich plexuses in the deeper layers of the epidermis and in the superficial layers of the dermis.[3,4,5,6] Each single fiber branches repeatedly and forms a network of fibers and naked nerve endings. The area covered by the terminal ramifications of a single afferent fiber is larger than has previously been suspected. Tower has, for example, cut down the afferent fibers leaving the cornea so that the action potential in a single fiber can be recorded. In such circumstances it was found that stimulation of a wide area of the cornea causes firing in the single remaining axon. This means that as much as an entire quadrant or more of the cornea may be innervated by the terminal ramifications of a single fiber. Weddell's study of the distribution of fibers around a zone of anesthesia formed by cutting a cutaneous nerve indicates that on the back of the hand a single nerve fiber may ramify in an area of a square centimeter or more.[3] In more proximal areas of the skin, the area supplied by a single axon is apparently much larger, and the distribution in the viscera may be even more widespread.[2] The terminal net formed by the ramifications of a single axon is closely and intricately interlaced with the terminal nets of other afferent fibers, forming a dense interlocking feltwork of terminal fibers. In the terminal net of a single afferent, anastomosis of fibers is of course present, but apparently there is no anatomical or protoplasmic continuity between the interlacing fibers of the various contributing fibers to the terminal net. There is thus no anatomical basis for fiber-to-fiber interaction in the fiber network according to more classical views of nerve conduction, but the close anatomical approximation and the development of varicosities at points of crossing of one fiber with another suggest the possibility that in this peripheral network synaptic or ephaptic connections might be established which would make it possible for impulses to spread from one fiber to another in the peripheral net. This possibility must serve as a logical limitation to studies which attempt to delimit the size of the peripheral anatomical distribution of a single fiber by the area which will cause discharge in a single dorsal root afferent.

In deeper structures the same interlocking terminal net derived from medullated and nonmedullated nerve fibers can also be made out, and we can therefore postulate a common peripheral mechanism for both cutaneous and deep pain, whether it originates in visceral or somatic structures; namely, in the terminal naked ramifications of specific afferent fibers.[2,5]

It has been known for some time that the stimulation of the peripheral end of a divided cutaneous nerve will occasionally cause pain referred to the peripheral distribution of an adjoining intact cutaneous nerve.[7] This has the clear physiological implication that antidromic stimulation of fibers in the distribution of one nerve spreads widely enough in peripheral structures to cause firing back into the central nervous system along afferent fibers in another nerve. This may imply an actual anatomical connection between these fibers, and indicate that the size of a single pain unit might be very large indeed. On the other hand, it may result from an ephaptic or synaptic type of transmission from one fiber distribution to another, either on the basis of direct electrical stimulation, or through a more complicated process of neurohumoral transmission, such as postulated by Sinclair, Weddell, and Feindel.[8] This subject will be more closely examined in a later section on the neurohistological basis for referred pain and hyperalgesia.

The size of the area over which a single pain unit is distributed is also indicated by the phenomenon to which Lewis drew attention as the nocifensor response. In some individuals the crushing of a minute portion of skin results in the development of an area of hyperalgesia around the point of crush. On the human forearm this area might be 10 to 12 cm. long and 4 to 5 cm. wide. If this response is due to some change in nervous excitability produced by impulses conveyed antidromically from the crushed area throughout the distribution of those units involved in the crush, then presumably a single unit might be expected to innervate as much as a quadrant of the involved area. If, however, as has been suggested, there is some form of communication between units on the basis of contact or neurohumoral diffusion rather than protoplasmic continuity, then the distribution of a single unit might be much smaller.

The Pain Spot: The concept of pain sensibility as dependent upon a relatively widely dispersed network interlaced with and overlapping other terminal networks