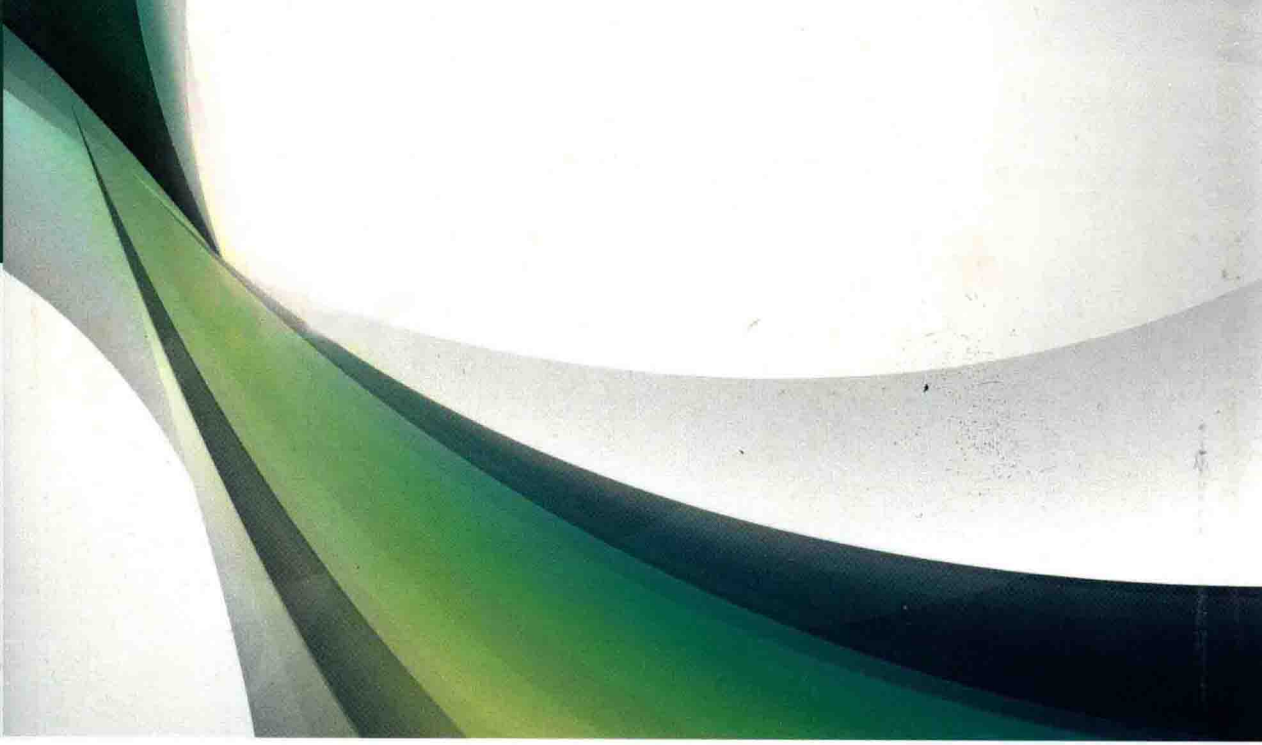

5th edition

Morgan & Mikhail's CLINICAL ANESTHESIOLOGY

John F. Butterworth • David C. Mackey • John D. Wasnick

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Morgan & Mikhail's Clinical Anesthesiology

FIFTH EDITION

John F. Butterworth IV, MD
Professor and Chairman
Department of Anesthesiology
Virginia Commonwealth University School of Medicine
VCU Health System
Richmond, Virginia

David C. Mackey, MD
Professor
Department of Anesthesiology and Perioperative Medicine
University of Texas M.D. Anderson Cancer Center
Houston, Texas

John D. Wasnick, MD, MPH
Steven L. Berk Endowed Chair for Excellence in Medicine
Professor and Chair
Department of Anesthesia
Texas Tech University Health Sciences Center
School of Medicine
Lubbock, Texas

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Chapter Authors

Gabriele Baldini, MD, MSc
Assistant Professor
Department of Anesthesia
McGill University
Montreal, Quebec

John F. Butterworth IV, MD
Professor and Chairman
Department of Anesthesiology
Virginia Commonwealth University School of Medicine
VCU Health System
Richmond, Virginia

Francesco Carli, MD, MPhil
Professor
Department of Anesthesia
McGill University
Montreal, Quebec

Charles E. Cowles, Jr, MD
Assistant Professor
Department of Anesthesiology
and Perioperative Medicine
Chief Safety Officer
Perioperative Enterprise
University of Texas MD Anderson Cancer Center
Houston, Texas

Michael A. Frölich, MD, MS
Associate Professor
Department of Anesthesiology
University of Alabama at Birmingham
Birmingham, Alabama

Martin Giesecke, MD
M.T. "Pepper" Jenkins Professor in Anesthesiology
Vice Chair, University Hospitals
Department of Anesthesiology and Pain Management
University of Texas Southwestern Medical Center
Dallas, Texas

Srikanth Hosur, MBBS, MD
Consultant in Intensive Care
QuestCare Intensivists
Dallas, Texas

Brian M. Ilfeld, MD, MS
Professor, In Residence
Department of Anesthesiology
University of California, San Diego
San Diego, California

David C. Mackey, MD
Professor
Department of Anesthesiology and
Perioperative Medicine
University of Texas M.D. Anderson Cancer Center
Houston, Texas

Sarah J. Madison, MD
Assistant Clinical Professor of Anesthesiology
Department of Anesthesiology
University of California, San Diego
San Diego, California

Edward R. Mariano, MD, MAS (Clinical Research)
Associate Professor of Anesthesia
Stanford University School of Medicine
Chief, Anesthesiology and Perioperative Care Service
VA Palo Alto Health Care System
Palo Alto, California

Brian P. McGlinch, MD
Associate Professor
Department of Anesthesiology
Mayo Clinic
Rochester, Minnesota
Colonel, United States Army Reserve, Medical Corps
452 Combat Support Hospital
Fort Snelling, Minnesota

Michael Ramsay, MD, FRCA
Chairman Department of Anesthesiology
and Pain Management
Baylor University Medical Center
President Baylor Research Institute
Clinical Professor
University of Texas Southwestern Medical School
Dallas, Texas

Richard W. Rosenquist, MD
Chair, Pain Management Department
Anesthesiology Institute
Cleveland Clinic
Cleveland, Ohio

Bruce M. Vrooman, MD
Department of Pain Management
Anesthesiology Institute
Cleveland Clinic
Cleveland, Ohio

John D. Wasnick, MD, MPH
Steven L. Berk Endowed Chair for
Excellence in Medicine
Professor and Chair
Department of Anesthesia
Texas Tech University Health Sciences Center
School of Medicine
Lubbock, Texas

Contributors

Kallol Chaudhuri, MD, PhD
Professor
Department of Anesthesia
Texas Tech University Health Sciences Center
Lubbock, Texas

Swapna Chaudhuri, MD, PhD
Professor
Department of Anesthesia
Texas Tech University Health Sciences Center
Lubbock, Texas

John Emhardt, MD
Department of Anesthesia
Indiana University School of Medicine
Indianapolis, Indiana

Suzanne N. Escudier, MD
Associate Professor
Department of Anesthesia
Texas Tech University Health Sciences Center
Lubbock, Texas

Aschraf N. Farag, MD
Assistant Professor
Department of Anesthesia
Texas Tech University Health Sciences Center
Lubbock, Texas

Herbert Gonzalez, MD
Assistant Professor
Department of Anesthesia
Texas Tech University Health Sciences Center
Lubbock, Texas

Kyle Gunnerson, MD
Department of Anesthesiology
VCU School of Medicine
Richmond, Virginia

Robert Johnston, MD
Associate Professor
Department of Anesthesia
Texas Tech University Health Sciences Center
Lubbock, Texas

Sanford Littwin, MD
Assistant Professor
Department of Anesthesiology
St. Luke's Roosevelt Hospital Center and Columbia University College of Physicians and Surgeons
New York, New York

Alina Nicoara, MD
Assistant Professor
Department of Anesthesiology
Duke University Medical Center
Durham, North Carolina

Bettina Schmitz, MD, PhD
Associate Professor
Department of Anesthesia
Texas Tech University Health Sciences Center
Lubbock, Texas

Steven L. Shafer, MD
Department of Anesthesia
Stanford University School of Medicine
Palo Alto, California

Christiane Vogt-Harenkamp, MD, PhD
Assistant Professor
Department of Anesthesia
Texas Tech University Health Sciences Center
Lubbock, Texas

Denise J. Wedel, MD
Professor of Anesthesiology
Mayo Clinic
Rochester, Minnesota

Gary Zaloga, MD
Global Medical Affairs
Baxter Healthcare
Deerfield, Illinois

Research and Review

Jacqueline E. Geier, MD
Resident, Department of Anesthesiology
St. Luke's Roosevelt Hospital Center
New York, New York

Brian Hirsch, MD
Resident, Department of Anesthesiology
Texas Tech University Medical Center
Lubbock, Texas

Shane Huffman, MD
Resident, Department of Anesthesiology
Texas Tech University Medical Center
Lubbock, Texas

Rahul K. Mishra, MD
Resident, Department of Anesthesiology
Texas Tech University Medical Center
Lubbock, Texas

Cecilia N. Pena, MD
Resident, Department of Anesthesiology
Texas Tech University Medical Center Hospital
Lubbock, Texas

Charlotte M. Walter, MD
Resident, Department of Anesthesiology
Texas Tech University Medical Center
Lubbock, Texas

Karvier Yates, MD
Resident, Department of Anesthesiology
Texas Tech University Medical Center
Lubbock, Texas

Foreword

A little more than 25 years ago, Alexander Kugushev, then the editor for Lange Medical Publications, approached us to consider writing an introductory textbook in the specialty of anesthesiology that would be part of the popular Lange series of medical books. Mr. Kugushev proved to be a convincing salesman, in part by offering his experience with scores of authors, all of whom opined that their most satisfying career achievement was the fathering of their texts. We could not agree more.

Now in its fifth edition, the overall stylistic goal of *Clinical Anesthesiology* remains unchanged: to be written simply enough so that a third year medical student can understand all essential basic concepts, yet comprehensively enough to provide a strong foundation for a resident in anesthesiology. To quote C. Philip Larson, Jr, MD from the Foreword of the first edition: "The text is complete; nothing of consequence is omitted. The writing style is precise, concise and highly readable."

The fifth edition features three new chapters: Ambulatory, Nonoperating Room, and Office-based Anesthesia; Perioperative Pain Management and Enhanced Outcomes; and Safety, Quality, and Performance Improvement. There are approximately 70 new figures and 20 new tables. The adoption of full color dramatically improves the aesthetic appeal of every page.

However, the biggest and most important change in the fifth edition is the "passing of the baton" to a distinguished and accomplished team of authors and editors. We were thrilled to learn that Drs. Butterworth, Mackey, and Wasnick would be succeeding us. The result of their hard work proves our enthusiasm was justified as they have taken *Clinical Anesthesiology* to a new level. We hope you, the readers, agree!

G. Edward Morgan, Jr, MD
Maged S. Mikhail, MD

Preface

Authors should be proud whenever a book is sufficiently successful to require a new edition. This is especially true when a book's consistent popularity over time leads to the succession of the original authors by a new set of authors. This latter circumstance is the case for the fifth edition of what most of us call "Morgan and Mikhail." We hope that you the reader will find this new edition as readable and useful as you have found the preceding four editions of the work.

This fifth edition, while retaining essential elements of its predecessors, represents a significant revision of the text. Only those who have written a book of this size and complexity will understand just how much effort was involved. Entirely new subjects (eg, Perioperative Pain Management and Enhanced Outcomes) have been added, and many other topics that previously lived in multiple chapters have been moved and consolidated. We have tried to eliminate redundancies and contradictions. The number of illustrations devoted to regional anesthesia and analgesia has been greatly increased to adequately address the rapidly growing importance of this perioperative management topic. The clarity of the illustrations is also enhanced by the widespread use of color throughout the book. We hope the product of this endeavor provides readers with as useful an exercise as was experienced by the authors in composing it.

- **Key Concepts** are listed at the beginning of each chapter and a corresponding numbered icon identifies the section(s) within the chapter in which each concept is discussed. These should help the reader focus on important concepts that underlie the core of anesthesiology.
- **Case Discussions** deal with clinical problems of current interest and are intended to stimulate discussion and critical thinking.
- The suggested reading has been revised and updated to include pertinent Web addresses and references to clinical practice guidelines and practice parameters. We have not tried to provide a comprehensive list of references: we expect that most readers of this text would normally perform their own literature searches on medical topics using Google, PubMed, and other electronic resources. Indeed, we expect that an ever-increasing segment of our readers will access this text in one of its several electronic forms.
- Multiple new illustrations and images have been added to this edition.

Nonetheless, our goal remains the same as that of the first edition: "to provide a concise, consistent presentation of the basic principles essential to the modern practice of anesthesia."

We would like to thank Brian Belval, Harriet Lebowitz, and Marsha Loeb for their invaluable assistance.

Despite our best intentions, various errors may have made their way into the fifth edition. We will be grateful to readers who report these to us at mm5edition@gmail.com so that we can correct them in reprints and future editions.

John F. Butterworth IV, MD
David C. Mackey, MD
John D. Wasnick, MD, MPH

Contents

CHAPTER 1

The Practice of Anesthesiology

KEY CONCEPTS

1. Oliver Wendell Holmes in 1846 was the first to propose use of the term *anesthesia* to denote the state that incorporates amnesia, analgesia, and narcosis to make painless surgery possible.
2. Ether was used for frivolous purposes ("ether frolics") and was not used as an anesthetic agent in humans until 1842, when Crawford W. Long and William E. Clark independently used it on patients. On October 16, 1846, William T.G. Morton conducted the first publicized demonstration of general anesthesia for surgical operation using ether.
3. The original application of modern local anesthesia is credited to Carl Koller, at the time a house officer in ophthalmology, who demonstrated topical anesthesia of the eye with cocaine in 1884.
4. Curare greatly facilitated tracheal intubation and muscle relaxation during surgery. For the first time, operations could be performed on patients without the requirement that relatively deep levels of inhaled general anesthetic be used to produce muscle relaxation.
5. John Snow, often considered the father of the anesthesia specialty, was the first to scientifically investigate ether and the physiology of general anesthesia.
6. The "captain of the ship" doctrine, which held the surgeon responsible for every aspect of the patient's perioperative care (including anesthesia), is no longer a valid notion when an anesthesiologist is present.

The Greek philosopher Dioscorides first used the term *anesthesia* in the first century AD to describe the narcotic-like effects of the plant mandragora. The term subsequently was defined in Bailey's *An Universal Etymological English Dictionary* (1721) as "a defect of sensation" and again in the *Encyclopedia Britannica* (1771) as "privation of the senses."

1 Oliver Wendell Holmes in 1846 was the first to propose use of the term to denote the state that incorporates amnesia, analgesia, and narcosis to make painless surgery possible. In the United States, use of the term *anesthesiology* to denote the practice or study of anesthesia was first proposed in the second decade of the twentieth century to emphasize the growing scientific basis of the specialty.

Although anesthesia now rests on scientific foundations comparable to those of other specialties, the practice of anesthesia remains very much a mixture of science and art. Moreover, the practice has expanded well beyond rendering patients insensible to pain during surgery or obstetric delivery (Table 1–1). The specialty uniquely requires a working familiarity with a long list of other specialties, including surgery and its subspecialties, internal medicine, pediatrics, and obstetrics as well as clinical pharmacology, applied physiology, and biomedical

TABLE 1–1 Definition of the practice of anesthesiology within the practice of medicine.[1]

Assessment and preparation of patients for surgery and anesthesia.
Prevention, diagnosis, and treatment of pain during and following surgical, obstetric, therapeutic, and diagnostic procedures.
Acute care of patients during the perioperative period.
Diagnosis and treatment of critical illness.
Diagnosis and treatment of acute, chronic, and cancer-related pain.
Cardiac, pulmonary, and trauma resuscitation.
Evaluation of respiratory function and application of treatments in respiratory therapy.
Instruction, evaluation of the performance, and supervision of both medical and paramedical personnel involved in perioperative care.
Administration in health care facilities, organizations, and medical schools necessary to implement these responsibilities.
Conduct of clinical, translational, and basic science research.

[1]Data from the American Board of Anesthesiology Booklet of Information, February 2012.

technology. Recent advances in biomedical technology, neuroscience, and pharmacology continue to make anesthesia an intellectually stimulating and rapidly evolving specialty. Many physicians entering residency positions in anesthesiology will already have multiple years of graduate medical education and perhaps even certification in other medical specialties.

This chapter reviews the history of anesthesia, emphasizing its British and American roots, and considers the current scope of the specialty.

The History of Anesthesia

The specialty of anesthesia began in the mid-nineteenth century and became firmly established less than six decades ago. Ancient civilizations had used opium poppy, coca leaves, mandrake root, alcohol, and even phlebotomy (to the point of unconsciousness) to allow surgeons to operate. Ancient Egyptians used the combination of opium poppy (containing morphine) and hyoscyamus (containing scopolamine); a similar combination, morphine and scopolamine, has been used parenterally for premedication. What passed for regional anesthesia in ancient times consisted of compression of nerve trunks (nerve ischemia) or the application of cold (cryoanalgesia). The Incas may have practiced local anesthesia as their surgeons chewed coca leaves and applied them to operative wounds, particularly prior to trephining for headache.

The evolution of modern surgery was hampered not only by a poor understanding of disease processes, anatomy, and surgical asepsis but also by the lack of reliable and safe anesthetic techniques. These techniques evolved first with inhalation anesthesia, followed by local and regional anesthesia, and finally intravenous anesthesia. The development of surgical anesthesia is considered one of the most important discoveries in human history.

INHALATION ANESTHESIA

Because the hypodermic needle was not invented until 1855, the first general anesthetics were destined to be inhalation agents. Diethyl ether (known at the time as "sulfuric ether" because it was produced by a simple chemical reaction between ethyl alcohol and sulfuric acid) was originally prepared in 1540 by Valerius Cordus. Ether was used for frivolous purposes ("ether frolics"), but not as an anesthetic agent in humans until 1842, when Crawford W. Long and William E. Clark independently used it on patients for surgery and dental extraction, respectively. However, they did not publicize their discovery. Four years later, in Boston, on October 16, 1846, William T.G. Morton conducted the first publicized demonstration of general anesthesia for surgical operation using ether. The dramatic success of that exhibition led the operating surgeon to exclaim to a skeptical audience: "Gentlemen, this is no humbug!"

Chloroform was independently prepared by von Leibig, Guthrie, and Soubeiran in 1831. Although first used by Holmes Coote in 1847,

chloroform was introduced into clinical practice by the Scot Sir James Simpson, who administered it to his patients to relieve the pain of labor. Ironically, Simpson had almost abandoned his medical practice after witnessing the terrible despair and agony of patients undergoing operations without anesthesia.

Joseph Priestley produced nitrous oxide in 1772, and Humphry Davy first noted its analgesic properties in 1800. Gardner Colton and Horace Wells are credited with having first used nitrous oxide as an anesthetic for dental extractions in humans in 1844. Nitrous oxide's lack of potency (an 80% nitrous oxide concentration results in analgesia but not surgical anesthesia) led to clinical demonstrations that were less convincing than those with ether.

Nitrous oxide was the least popular of the three early inhalation anesthetics because of its low potency and its tendency to cause asphyxia when used alone (see Chapter 8). Interest in nitrous oxide was revived in 1868 when Edmund Andrews administered it in 20% oxygen; its use was, however, overshadowed by the popularity of ether and chloroform. Ironically, nitrous oxide is the only one of these three agents still in widespread use today. Chloroform superseded ether in popularity in many areas (particularly in the United Kingdom), but reports of chloroform-related cardiac arrhythmias, respiratory depression, and hepatotoxicity eventually caused practitioners to abandon it in favor of ether, particularly in North America.

Even after the introduction of other inhalation anesthetics (ethyl chloride, ethylene, divinyl ether, cyclopropane, trichloroethylene, and fluroxene), ether remained the standard inhaled anesthetic until the early 1960s. The only inhalation agent that rivaled ether's safety and popularity was cyclopropane (introduced in 1934). However, both are highly combustible and both have since been replaced by a succession of nonflammable potent fluorinated hydrocarbons: halothane (developed in 1951; released in 1956), methoxyflurane (developed in 1958; released in 1960), enflurane (developed in 1963; released in 1973), and isoflurane (developed in 1965; released in 1981).

Two newer agents are now the most popular in developed countries. Desflurane (released in 1992), has many of the desirable properties of isoflurane as well as more rapid uptake and elimination (nearly as fast as nitrous oxide). Sevoflurane, has low blood solubility, but concerns about the potential toxicity of its degradation products delayed its release in the United States until 1994 (see Chapter 8). These concerns have proved to be largely theoretical, and sevoflurane, not desflurane, has become the most widely used inhaled anesthetic in the United States, largely replacing halothane in pediatric practice.

LOCAL & REGIONAL ANESTHESIA

The medicinal qualities of coca had been used by the Incas for centuries before its actions were first observed by Europeans. Cocaine was isolated from coca leaves in 1855 by Gaedicke and was purified in 1860 by Albert Niemann. The original application of modern local anesthesia is credited to Carl Koller, at the time a house officer in ophthalmology, who demonstrated topical anesthesia of the eye with cocaine in 1884. Later in 1884 William Halsted used cocaine for intradermal infiltration and nerve blocks (including blocks of the facial nerve, brachial plexus, pudendal nerve, and posterior tibial nerve). August Bier is credited with administering the first spinal anesthetic in 1898. He was also the first to describe intravenous regional anesthesia (Bier block) in 1908. Procaine was synthesized in 1904 by Alfred Einhorn and within a year was used clinically as a local anesthetic by Heinrich Braun. Braun was also the first to add epinephrine to prolong the duration of local anesthetics. Ferdinand Cathelin and Jean Sicard introduced caudal epidural anesthesia in 1901. Lumbar epidural anesthesia was described first in 1921 by Fidel Pages and again (independently) in 1931 by Achille Dogliotti. Additional local anesthetics subsequently introduced include dibucaine (1930), tetracaine (1932), lidocaine (1947), chloroprocaine (1955), mepivacaine (1957), prilocaine (1960), bupivacaine (1963), and etidocaine (1972). The most recent additions, ropivacaine and levobupivacaine, have durations of action similar to bupivacaine but less cardiac toxicity (see Chapter 16).

INTRAVENOUS ANESTHESIA

Induction Agents

Intravenous anesthesia required the invention of the hypodermic syringe and needle by Alexander Wood in 1855. Early attempts at intravenous anesthesia included the use of chloral hydrate (by Oré in 1872), chloroform and ether (Burkhardt in 1909), and the combination of morphine and scopolamine (Bredenfeld in 1916). Barbiturates were first synthesized in 1903 by Fischer and von Mering. The first barbiturate used for induction of anesthesia was diethylbarbituric acid (barbital), but it was not until the introduction of hexobarbital in 1927 that barbiturate induction became popular. Thiopental, synthesized in 1932 by Volwiler and Tabern, was first used clinically by John Lundy and Ralph Waters in 1934 and for many years remained the most common agent for intravenous induction of anesthesia. Methohexital was first used clinically in 1957 by V. K. Stoelting and is the only other barbiturate used for induction of anesthesia in humans. After chlordiazepoxide was discovered in 1955 and released for clinical use in 1960, other benzodiazepines—diazepam, lorazepam, and midazolam—came to be used extensively for premedication, conscious sedation, and induction of general anesthesia. Ketamine was synthesized in 1962 by Stevens and first used clinically in 1965 by Corssen and Domino; it was released in 1970 and continues to be popular today, particular when administered in combination with other agents. Etomidate was synthesized in 1964 and released in 1972. Initial enthusiasm over its relative lack of circulatory and respiratory effects was tempered by evidence of adrenal suppression, reported after even a single dose. The release of propofol in 1986 (1989 in the United States) was a major advance in outpatient anesthesia because of its short duration of action (see Chapter 9). Propofol is currently the most popular agent for intravenous induction worldwide.

Neuromuscular Blocking Agents

The introduction of curare by Harold Griffith and Enid Johnson in 1942 was a milestone in anesthesia.

Curare greatly facilitated tracheal intubation and muscle relaxation during surgery. For the first time, operations could be performed on patients without the requirement that relatively deep levels of inhaled general anesthetic be used to produce muscle relaxation. Such large doses of anesthetic often resulted in excessive cardiovascular and respiratory depression as well as prolonged emergence. Moreover, larger doses were often not tolerated by frail patients.

Succinylcholine was synthesized by Bovet in 1949 and released in 1951; it has become a standard agent for facilitating tracheal intubation during rapid sequence induction. Until recently, succinylcholine remained unchallenged in its rapid onset of profound muscle relaxation, but its side effects prompted the search for a comparable substitute. Other neuromuscular blockers (NMBs; discussed in Chapter 11)—gallamine, decamethonium, metocurine, alcuronium, and pancuronium—were subsequently introduced. Unfortunately, these agents were often associated with side effects (see Chapter 11), and the search for the ideal NMB continued. Recently introduced agents that more closely resemble an ideal NMB include vecuronium, atracurium, rocuronium, and *cis*-atracurium.

Opioids

Morphine, isolated from opium in 1805 by Sertürner, was also tried as an intravenous anesthetic. The adverse events associated with large doses of opioids in early reports caused many anesthetists to avoid opioids and favor pure inhalation anesthesia. Interest in opioids in anesthesia returned following the synthesis and introduction of meperidine in 1939. The concept of *balanced anesthesia* was introduced in 1926 by Lundy and others and evolved to include thiopental for induction, nitrous oxide for amnesia, an opioid for analgesia, and curare for muscle relaxation. In 1969, Lowenstein rekindled interest in "pure" opioid anesthesia by reintroducing the concept of large doses of opioids as complete anesthetics. Morphine was the first agent so employed, but fentanyl and sufentanil have been preferred by a large margin as sole agents. As experience grew with this technique, its multiple limitations—unreliably preventing patient awareness, incompletely suppressing autonomic responses during surgery, and prolonged respiratory depression—were realized.

Remifentanil, an opioid subject to rapid degradation by nonspecific plasma and tissue esterases, permits profound levels of opioid analgesia to be employed without concerns regarding the need for postoperative ventilation.

EVOLUTION OF THE SPECIALTY

British Origins

Following its first public demonstration in the United States, ether anesthesia quickly was adopted in England. John Snow, often considered the father of the anesthesia specialty, was the first physician to take a full-time interest in this new anesthetic. He was the first to scientifically investigate ether and the physiology of general anesthesia. Of course, Snow was also a pioneer in epidemiology. He helped stop a cholera epidemic in London by proving that the causative agent was transmitted by ingestion of contaminated well water rather than by inhalation. In 1847, Snow published the first book on general anesthesia, *On the Inhalation of Ether*. When the anesthetic properties of chloroform were made known, he quickly investigated and developed an inhaler for that agent as well. He believed that an inhaler should be used in administering ether or chloroform to control the dose of the anesthetic. His second book, *On Chloroform and Other Anaesthetics*, was published posthumously in 1858.

After Snow's death, Dr. Joseph T. Clover took his place as England's leading anesthetist. Clover emphasized continuously monitoring the patient's pulse during anesthesia, a practice that was not yet standard at the time. He was the first to use the jaw-thrust maneuver for relieving airway obstruction, the first to insist that resuscitation equipment always be available during anesthesia, and the first to use a cricothyroid cannula (to save a patient with an oral tumor who developed complete airway obstruction). After Clover, Sir Frederic Hewitt became England's foremost anesthetist at the turn of the last century. He was responsible for many inventions, including the oral airway. Hewitt also wrote what many consider to be the first true textbook of anesthesia, which went through five editions. Snow, Clover, and Hewitt established the tradition of physician anesthetists in England. In 1893, the first organization of physician specialists in anesthesia, the London Society of Anaesthetists, was formed in England by J.F. Silk.

The first elective tracheal intubations during anesthesia were performed in the late nineteenth century by surgeons Sir William MacEwen in Scotland, Joseph O'Dwyer in the United States, and Franz Kuhn in Germany. Tracheal intubation during anesthesia was popularized in England by Sir Ivan Magill and Stanley Rowbotham in the 1920s.

American Origins

In the United States, only a few physicians had specialized in anesthesia by 1900. The task of providing general anesthesia was often delegated to junior surgical house officers or medical students, if they were available.

The first organization of physician anesthetists in the United States was the Long Island Society of Anesthetists formed in 1905, which, as it grew, was renamed the New York Society of Anesthetists in 1911. The International Anesthesia Research Society (IARS) was founded in 1922, and in that same year the IARS-sponsored scientific journal *Current Researches in Anesthesia and Analgesia* (now called *Anesthesia and Analgesia*) began publication. In 1936, the New York Society of Anesthetists became the American Society of Anesthetists, and later, in 1945, the American Society of Anesthesiologists (ASA). The scientific journal *Anesthesiology* was first published in 1940.

Four physicians stand out in the early development of anesthesia in the United States after 1900: F.H. McMechan, Arthur E. Guedel, Ralph M. Waters, and John S. Lundy. McMechan was the driving force behind both the IARS and *Current Researches in Anesthesia and Analgesia*, and tirelessly organized physicians specializing in anesthesia into national and international organizations until his death in 1939. Guedel was the first to describe the signs and stages of general anesthesia. He advocated cuffed tracheal tubes and introduced artificial ventilation during ether anesthesia (later termed *controlled respiration* by

Waters). Ralph Waters made a long list of contributions to the specialty, probably the most important of which was his insistence on the proper education of specialists in anesthesia. Waters developed the first academic department of anesthesiology at the University of Wisconsin in Madison. Lundy was instrumental in the formation of the American Board of Anesthesiology and chaired the American Medical Association's Section on Anesthesiology for 17 years.

Because of the scarcity of physicians specializing in anesthesia in the United States and the perceived relative safety of ether anesthesia, surgeons at both the Mayo Clinic and Cleveland Clinic began training and employing nurses as anesthetists in the early 1900s. As the numbers of nurse anesthetists increased, a national organization (now called the American Association of Nurse Anesthetists) was incorporated in 1932. The AANA first offered a certification examination in 1945. In 1969 two Anesthesiology Assistant programs began accepting students, and in 1989 the first certification examinations for AAs were administered. Certified Registered Nurse Anesthetists and Anesthesiologist Assistants represent important members of the anesthesia workforce in the United States and in other countries.

Official Recognition

In 1889 Henry Isaiah Dorr, a dentist, was appointed Professor of the Practice of Dentistry, Anaesthetics and Anaesthesia at the Philadelphia College of Dentistry. Thus he was the first known professor of anesthesia worldwide. Thomas D. Buchanan, of the New York Medical College, was the first physician to be appointed Professor of Anesthesia (in 1905). When the American Board of Anesthesiology was established in 1938, Dr. Buchanan served as its first president. In England, the first examination for the Diploma in Anaesthetics took place in 1935, and the first Chair in Anaesthetics was awarded to Sir Robert Macintosh in 1937 at Oxford University. Anesthesia became an officially recognized specialty in England only in 1947, when the Royal College of Surgeons established its Faculty of Anaesthetists. In 1992 an independent Royal College of Anaesthetists was granted its charter.

The Scope of Anesthesia

The practice of anesthesia has changed dramatically since the days of John Snow. The modern anesthesiologist is now both a perioperative consultant and a primary deliverer of care to patients. In general, anesthesiologists manage nearly all "noncutting" aspects of the patient's medical care in the immediate perioperative period. The "captain of the ship" doctrine, which held the surgeon responsible for every aspect of the patient's perioperative care (including anesthesia), is no longer a valid notion when an anesthesiologist is present. The surgeon and anesthesiologist must function together as an effective team, and both are ultimately answerable to the patient rather than to each other.

The modern practice of anesthesia is not confined to rendering patients insensible to pain (Table 1–1). Anesthesiologists monitor, sedate, and provide general or regional anesthesia outside the operating room for various imaging procedures, endoscopy, electroconvulsive therapy, and cardiac catheterization. Anesthesiologists have traditionally been pioneers in cardiopulmonary resuscitation and continue to be integral members of resuscitation teams.

An increasing number of practitioners pursue a subspecialty in anesthesia for cardiothoracic surgery (see Chapter 22), critical care (see Chapter 57), neuroanesthesia (see Chapter 27), obstetric anesthesia (see Chapter 41), pediatric anesthesia (see Chapter 42), and pain medicine (see Chapter 47). Certification requirements for special competence in critical care and pain medicine already exist in the United States. Fellowship programs in Adult Cardiothoracic Anesthesia and Pediatric Anesthesiology have specific accreditation requirements, and soon those in Obstetric Anesthesiology will as well. A certification examination will soon be available in Pediatric Anesthesiology. Education and certification in anesthesiology can also be used as the basis for certification in Sleep Medicine or in Palliative Medicine.

Anesthesiologists are actively involved in the administration and medical direction of many ambulatory surgery facilities, operating room suites, intensive care units, and respiratory therapy