Chapter 1

History of anesthesia

Rafael A. Ortega and Christine Mai

It has been said that the disadvantage of not understanding the past is to not understand the present. Knowledge of the history of anesthesia enables us to appreciate the discoveries that shaped this medical field, to recognize the scope of anesthesiology today, and to predict future advancements (Table 1.1).

It is generally agreed that the first successful public demonstration of general inhalation anesthesia with diethyl ether occurred in Boston in the 19th century. Prior to this occasion, all but the simplest procedures in surgery were "to be dreaded only less than death itself." Throughout history, pain prohibited surgical advances and consumed patients. Imagine the sense of awe and pride when William Thomas Green Morton (1819–1868), a dentist from Massachusetts, demonstrated the use of ether to anesthetize a young man for the removal of a tumor. The celebrated demonstration in 1846 at the Massachusetts General Hospital heralded a new era of pain-free operations. As Johann Friedrich Dieffenbach, author of *Ether against Pain*, stated, "Pain, the highest consciousness of our earthly existence, the most distinct sensation of the imperfection of our body, must bow before the power of the human mind, before the power of ether vapor."

Anesthesia prior to ether

The first forays into the field of anesthesiology occurred much earlier than Morton's demonstration. The Greek physician Dioscorides (A.D. 40–90), for instance, reported on the analgesic properties of mandragora, extracted from the bark and leaves of the mandrake plant in the first century. Agents such as ethyl alcohol, cannabis, and opium were inhaled by the ancients for their stupefying effects before surgery. Alchemist and physician Arnold of Villanova (c. 1238–c. 1310) used a mixture of opium, mandragora, and henbane to make his patients insensible to pain.

From the ninth to the 13th century, the "soporific sponge" was used to provide pain relief. These sponges were impregnated with a liquid made from boiling a combination of mandrake leaves, poppies, and herbs. Prior to surgery, the sponge was reconstituted with hot water and placed over the nostrils of the afflicted to deliver the anesthetic. Alcohol fumes also were used in the surgical setting during the Middle Ages, but proved to be of poor value because of their inadequacy both in pain relief and in minimizing the recollection of unpleasant memories of the surgical procedure.

In the 16th century, Paracelsus (1493–1544) produced laudanum, an opium derivative in the form of a tincture. Laudanum, or "wine of opium," was used as an analgesic but also was inappropriately prescribed for meningitis, cardiac disease, and tuberculosis. Still, alcohol and opium were regarded as of practical value in diminishing the pain of operations by the mid-1800s, despite their relative ineffectiveness.

In 1804, decades before Morton's demonstration, Seishu Hanaoka (1760–1835), a surgeon in Japan, administered general anesthesia. Hanaoka used an herbal concoction containing a combination of potent anticholinergic alkaloids capable of inducing unconsciousness. The patients drank the preparation known as "Tsusensan" before Hanaoka performed surgery. It is also known that Chinese physicians have used acupuncture to ease surgical pain for centuries.

Nitrous oxide

Joseph Priestley (1733–1804), an English clergyman and chemist, first described nitrous oxide's properties as an anesthetic. Like ether, nitrous oxide was known for its ability to produce lightheadedness and inebriation. Sir Humphry Davy (1778–1829) noted the gas's effect on respiration and the central nervous system. In his book *Nitrous Oxide*, Davy commented on its effects of transiently relieving headaches and toothaches and its capability to alleviate physical pain during surgical procedures. The term *laughing gas* was coined by Davy because of its ability to trigger uncontrollable laughter. This gas remains the oldest inhaled anesthetic still used today.

Diethyl ether

The compound diethyl ether has been known for centuries. It may have been first discovered by the Arabian philosopher Jabir ibn Hayyam in the eighth century. Credit also is given to the 13th century European alchemist Raymundus Lullius, who first called it "sweet vitriol." This compound later was renamed *ether*, which in Greek means "the upper, pure bright air." By the 16th century, Paracelsus recognized and recorded the analgesic properties of ether. He noted that it produced drowsiness in chickens, causing them to fall asleep and awaken unharmed.

Table 1.1. Timeline of the history of anesthesia

First century A.D.	Greek physician Dioscorides reports analgesic properties of mandragora
Ninth–13th century	Soporific sponge method for delivering pain relief
16th century	Paracelsus introduces laudanum, "wine of opium." Spanish conquistadores' account of curare in South America
18th century	
1773	Nitrous oxide first introduced by Joseph Priestley
19th century	
1800	Humphry Davy publishes *Nitrous Oxide*
1804	Seishu Hanaoka of Japan administers general anesthesia
1842	Crawford Long administers diethyl ether inhalational general anesthesia
1844	Horace Wells administers nitrous oxide for dental analgesia
1846	William Morton's public demonstration of diethyl ether at Massachusetts General Hospital
1847	James Young Simpson administers chloroform for general anesthesia in England
1853	John Snow administers chloroform to Queen Victoria for the birth of Prince Leopold
1857	Claude Bernard discovers the effects of curare located at the myoneural junction
1884	Carl Koller introduces the use of cocaine for ophthalmic surgery
1885	William Halsted describes techniques of anesthetizing nerve plexuses using cocaine
1889	August Bier performs the first surgical spinal anesthesia
20th century	
1903	Phenobarbital synthesized by Fischer and von Mering
1905	Procaine introduced as a local anesthetic Long Island Society of Anesthetists founded
1911	Long Island Society of Anesthetists becomes the New York Society of Anesthetists
1927	Ralph Waters establishes first anesthesiology postgraduate training program at the University of Wisconsin–Madison
1932	Thiopental and thiamylal synthesized
1934	Thiopental used by both Waters and Lundy for induction of anesthesia
1935	Emery Rovenstine organizes an anesthesia department at Bellevue Hospital, NY
1936	New York Society of Anesthetists becomes the American Society of Anesthetists
1938	The American Board of Anesthesiology founded
1940	William Lemmon introduces concept of continuous spinal anesthesia
1942	Drug form of curare, intocostrin, introduced
1943	Lidocaine introduced as local anesthetic by Lofgren and Lindquist of Sweden
1944	Edward Tuohy invents the Tuohy needle
1945	American Society of Anesthetists becomes the American Society of Anesthesiologists (ASA)
1949	Daniel Bovet synthesizes succinylcholine
1951	Halothane introduced into clinical practice
1960	Methoxyflurane introduced into clinical practice; its use was limited by nephrotoxicity
1962	Ketamine synthesized
1964	Etomidate synthesized
1965	Isoflurane first introduced; it was marketed in the 1970s
1977	Propofol synthesized
1983	Archie Brain develops the laryngeal mask airway
1985	Anesthesia Patient Safety Foundation established
1986	Standards for basic anesthesia monitoring approved by the ASA House of Delegates
1992	Desflurane introduced into clinical practice
1994	Sevoflurane introduced into clinical practice
1995–present:	The past decade has seen advances in a variety of areas, including refinements in anesthesia delivery apparatus, ultrasound applications for regional anesthesia, transesophageal echocardiography, depth of anesthesia monitors, total intravenous anesthetics, supraglottic airway devices, and other innovations, helping to make the administration of anesthesia safer.

Before ether became known as a general anesthetic, it was marketed as a pain reliever. It also was used as an inexpensive recreational drug during "ether frolics." Many famous British scientists, such as Robert Boyle (1627–1691), Isaac Newton (1643–1728), and Michael Faraday (1791–1867), examined the properties of ether. However, they did not make the connection between its analgesic qualities and the possibility of complete surgical anesthesia. It was not until later that ether was used as a general anesthetic. Crawford Williamson Long (1815–1978), a physician from Georgia, administered ether on March 30, 1842, to James M. Venable for the removal of a neck tumor. Long also conducted comparative trials of procedures, with and without ether, to demonstrate that alleviation of pain was a result of the drug rather than individual pain threshold or hypnotism.

Horace Wells (1815–1848) was first in attempting to publicly demonstrate general anesthesia. Wells, a dentist, knew of the analgesic effects of nitrous oxide and used it for tooth extractions. Understanding its effects, he attempted to demonstrate a painless tooth extraction at Harvard Medical School in 1845. Perhaps because of the low potency of nitrous oxide, during the procedure the subject moved and groaned. Wells was discredited for his display. Deeply disappointed by the

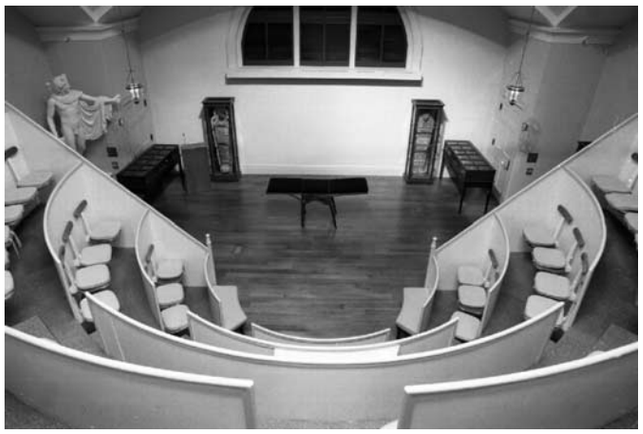

Figure 1.1. The Ether Dome, designed by architect Charles Bulfinch, was originally known as the Surgical Amphitheater of Massachusetts General Hospital.

failed demonstration, he committed suicide in 1848. Nevertheless, his idea inspired individuals such as Morton to persist in demonstrating the efficacy of these drugs. On October 16, 1846, Morton administered ether, allowing surgeon John Collins Warren (1778–1856) to painlessly remove a mandible tumor from Edward Gilbert Abbott. This event took place in the surgical amphitheater at Massachusetts General Hospital, which is now known as the Ether Dome, a designated national historical landmark (Fig. 1.1). The account of the ether demonstration appeared the next day in the *Boston Daily Journal*, and within months the discovery of surgical anesthesia was known worldwide.

The ether controversy

Ether anesthesia proved to be controversial from the start. Morton wanted to capitalize on the discovery and initially refused to divulge the identity of the agent in his inhaler (Fig. 1.2). Wells and chemist Charles T. Jackson (1805–1880), Morton's advisor, both claimed the discovery belonged to them. Jackson, a Boston physician and chemistry professor, was well aware of the failed public demonstrations of the past and had advised Morton to use ether rather than nitrous oxide in his historical debut. For this contribution, Jackson adamantly argued it was he who should be credited for the "idea" of administering

Figure 1.2. A replica of Morton's inhaler as used at the first public demonstration of ether anesthesia on October 16, 1846.

Figure 1.3. Bas-relief on the Ether Monument in Boston representing a surgical procedure in a hospital, with the patient under the influence of ether. To the left, an assistant is washing his hands in a basin, denoting an appreciation for early attempts at antisepsis.

ether-inhaled anesthesia. Wells contended that he had successfully administered general anesthesia with nitrous oxide on several occasions. However, he never convincingly proved it. Long also claimed he had demonstrated the uses of ether in rural areas well before Morton. However, Long did not publish his experiences until 1849, three years after Morton's demonstration. These debates have collectively been referred to as "the ether controversy."

In 1868, to commemorate the first public demonstration of ether in Boston, a monument was erected in the city's Public Garden. The Ether Monument, with its marble and granite images and inscriptions, addresses universal themes such as the suffering caused by war, the desire on behalf of loved ones to relieve pain, and the triumph of medical science (Fig. 1.3 and Fig. 1.4). Perhaps no other monument related to medicine is so rich in history, controversies, and allegories. The Ether Monument, however, makes no mention of any of the claimants to the discovery.

Acceptance of anesthesia in the Western world

In some ways, what matters most is not *who* discovered anesthesia, but rather *where* and *when* it was discovered. Some scholars believe that a spirit of humanitarianism and political freedom were necessary for the development of anesthesia to occur in the 19th century. Initially, there were religious objections to anesthesia. Certain individuals believed it was against the will of God to alleviate pain. The use of anesthesia in labor and delivery was particularly contentious, in part because of the "curse of Eve," which states, "In sorrow thou shalt bring forth children" (Genesis 3:16). Also on biblical grounds, others supported anesthesia, reasoning that God himself performed the first operation under "anesthesia" when he removed Adam's rib: "The Lord God caused a deep sleep to fall upon Adam and he slept…" (Genesis 2:21). Other objections to anesthesia were based on morality rather than the religious implications of pain relief. Some argued that anesthesia's disinhibiting effects threatened

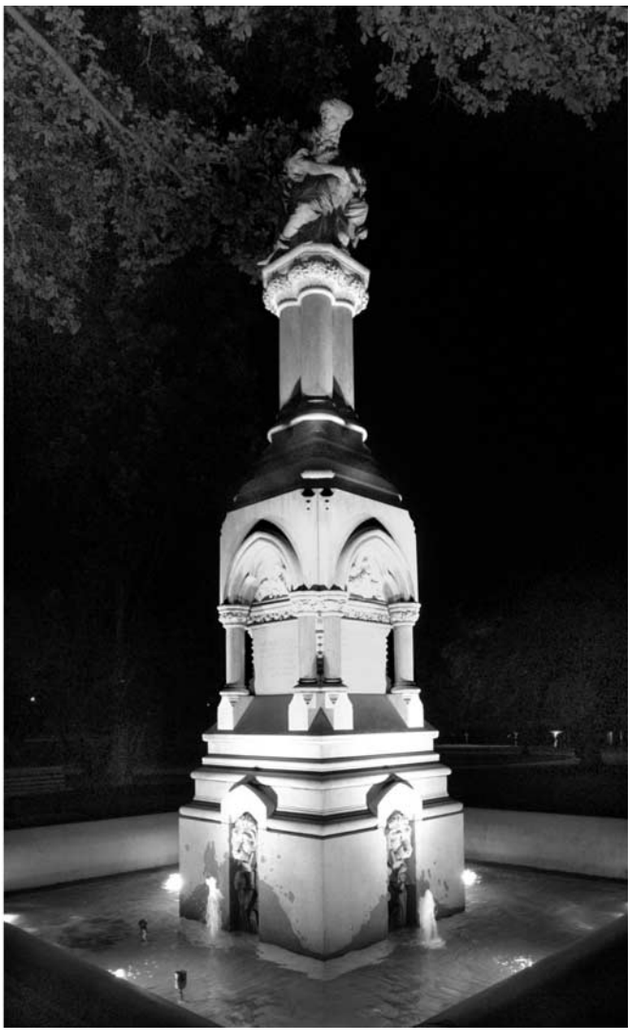

Figure 1.4. The Ether Monument in the Boston Public Garden, with evening illumination and working fountains.

the virtue and decency of women. In 1853, Queen Victoria effectively silenced all opposition when John Snow anesthetized her with chloroform during the birth of Prince Leopold.

Chloroform

Because ether was such a safe anesthetic, its administration was relegated largely to nonphysicians in the United States, whereas in England chloroform quickly became the anesthetic of choice. This preference might have arisen out of a sense of national pride, being that ether anesthesia was introduced in America, which had relatively recently gained its independence. Chloroform, a more dangerous drug than ether, required more skillful and careful titration. The resulting challenges of chloroform administration attracted the attention of brilliant physicians and investigators, including the Scottish obstetrician James Young Simpson (1811–1870) and the English anesthetist John Snow (1813–1858). This may explain why there were few developments in anesthesia within the United States for many decades after the introduction of ether while in Britain, great progress was made.

Modern inhaled anesthetics

The search for an ideal inhaled anesthetic led to the introduction of many chemicals, including ethyl chloride, ethylene, cyclopropane, and other volatile agents, during the first half of the 20th century. However, their use faded because of varied disadvantages, such as strong pungency, weak potency, and flammability. These agents soon were replaced by fluorinated hydrocarbons. Fluorination made inhaled anesthetics more stable, less combustible, and less toxic. In 1951, halothane was recognized as a superior anesthetic over its predecessors. In the 1960s, methoxyflurane was popular for a decade, until its dose-related nephrotoxicity discouraged its use. Enflurane and its isomer, isoflurane, were introduced in 1963 and 1965, respectively. Enflurane's popularity was limited after it was shown to produce cardiovascular depression and seizures. Isoflurane was more difficult to synthesize and purify than enflurane. However, once the purification process was refined and further trials proved its safety, isoflurane was marketed in the late 1970s and remains a popular anesthetic. For 20 years, no further developments occurred until the release of desflurane in 1992 and sevoflurane in 1994. Today, these three agents, in addition to nitrous oxide, constitute the mainstay of inhalation anesthetics.

Regional anesthesia

Although chloroform and ether provided analgesia for obstetric pain, disadvantages such as inadequate uterine contractions and neonatal respiratory depression were noted. The invention of the hollow needle in 1853 by Alexander Wood allowed for the development of regional anesthesia techniques as an effective alternative to inhaled anesthetics.

In 1884, Carl Koller (1858–1944), an ophthalmologist, introduced the use of cocaine for ophthalmic surgery. Within a year of his reports, injections of cocaine were described to anesthetize nerve trunks and the brachial plexus by William S. Halsted (1852–1922). The idea of spinal anesthesia first was conceived in 1885 by a neurologist, Leonard Corning (1855–1923). Although his writings described the administration of cocaine, the injection was extradural rather than in the subarachnoid space. Corning's technique was improved by the German physician Heinrich Quincke (1842–1922), who described the level below which it was safest to perform a lumbar puncture. In 1899, using Quincke's technique, August Bier (1861–1949) performed the first spinal anesthesia for a surgical procedure. The Swiss obstetrician Oscar Kreis recognized the advantages of regional anesthesia in obstetrics and administered the first spinal anesthesia for control of labor pain at the start of the 20th century.

Early cases of regional anesthesia were noted to have side effects, such as high incidences of postdural puncture headache, vomiting, and the propensity for the those administering it to

become addicted to cocaine. The addictive nature of cocaine and its toxicity led to the discovery of safer local anesthetics, such as procaine in 1905 and lidocaine in 1943. In 1940, the introduction of continuous spinal anesthesia was credited to William T. Lemmon, who advocated the administration of repeated small doses of procaine through a malleable needle connected to a rubber tubing and syringe. Four years later, Edward Tuohy (1908–1959) of the Mayo Clinic introduced two important modifications: the invention of the Tuohy needle and the idea of threading a catheter into the epidural space for incremental doses of local anesthetics. A technique for locating the epidural space was made popular by the writings of Achille M. Dogliotti (1897–1966), who identified it using the "loss of resistance."

Over the past 60 years, intrathecal and epidural administration of local anesthetics, opioids, and steroids has become commonplace for analgesia throughout the course of labor and for managing chronic pain. The development of plexus blocks and other regional anesthesia techniques progressed to incorporate the use of nerve stimulators and ultrasound to facilitate locating nerves, thus enhancing the quality of the block.

Neuromuscular blocking agents

Neuromuscular blocking agents were introduced into anesthetic practice nearly a century after the administration of inhalational anesthesia. Curare, the first isolated neuromuscular blocking agent, originally was used in hunting and tribal warfare by natives of South America. Curare alkaloid extracts from lianas (vines) were applied to arrow darts, which natives propelled using blowguns to poison their prey. Accounts of these Amazon jungle poisons by 16th century Spanish conquistadores intrigued the European medical community and triggered early experiments on animals, which determined that the agent paralyzes muscle function. The collaborative work of Benjamin Brodie (1783–1862) and Charles Waterton (1783–1865), demonstrated that animals injected with curare could survive with artificial ventilation. In 1857, Claude Bernard (1813–1878), a French physiologist, determined that the effect of the drug was located in neither the nerve nor the muscle, but at the junction of the two. Initially, there were limited medical applications for curare, such as ameliorating muscle spasms caused by tetanus, reducing trauma during seizure therapy, and treating Parkinson-like muscle rigidity. However, with the advent of tracheal intubation and mechanical ventilation, the use of curare to prevent laryngospasm during laryngoscopy or to relax abdominal muscles during surgery remarkably altered the practice of anesthesia.

On January 23, 1942, the drug form of curare, intocostrin, was introduced into anesthesia practice by anesthesiologist Harold R. Griffith (1894–1985) and his resident, Enid Johnson, at Montreal Homeopathic Hospital. The facilitation of tracheal intubation and abdominal muscle relaxation produced by intocostrin during cyclopropane anesthesia heralded a new era for neuromuscular blocking agent development. Subsequent muscle relaxants, such as gallamine, decamethonium, and metocurine, were studied. However, their popularity was limited because of undesirable autonomic nervous system effects. In 1949, succinylcholine, a depolarizing neuromuscular agent, was synthesized by Nobel laureate Daniel Bovet (1907–1992). Nondepolarizing neuromuscular drugs, such as the aminosteroids pancuronium, vecuronium and rocuronium and the benzylisoquinoliniums atracurium and *cis*-atracurium, were introduced in the late 20th century.

Intravenous anesthetics

The first intravenous induction agent was phenobarbital, a barbiturate synthesized by Emil Fischer (1852–1919) and Joseph von Mering in 1903. As a hypnotic, phenobarbital caused prolonged periods of unconsciousness and slow emergence. Hexobarbital, a short-acting oxybarbiturate, was introduced in 1932 but was subsequently replaced by a sulfated barbiturate, thiopental, a potent agent with rapid onset of action and few excitatory side effects. In 1934, both Ralph Waters (1883–1979) at the University of Wisconsin and John Lundy (1894–1973) at the Mayo Clinic successfully administered thiopental as an intravenous anesthetic agent. Furthermore, John Lundy's continued research on intravenous anesthetics popularized its use in clinical practice. His concept of "balanced anesthesia" emphasized combining multiple anesthetic drugs and techniques to provide hypnosis, muscle relaxation, and analgesia. This approach led to the optimization of operating conditions and reduction of side effects, thereby making anesthesia administration safer for patients. The widespread use of thiopental stimulated the development of other classes of intravenous hypnotics, including ketamine (1962), etomidate (1964), and propofol (1977). Benzodiazepines, opioids, antiemetics, and other drugs have enriched the intravenous pharmacologic armamentarium, and their combined use represents an extension of Lundy's approach of balanced anesthesia.

Anesthesiology as a medical specialty

The field of anesthesiology as a recognized medical specialty developed gradually in America during the 20th century. For decades, formal instruction in anesthesia was nonexistent and the field was practiced only by a few self-taught individuals. In the 1910s, Ralph Waters described the environment he encountered in which nurses administered anesthesia because there were few physicians trained as proficient anesthetists. He advocated the development of dedicated anesthesia departments and training programs. Subsequently, several anesthesiologists, including Thomas D. Buchanan and John Lundy, established anesthesia departments at New York Medical College and the Mayo Clinic, respectively. The first anesthesiology postgraduate training program was established by Waters at the University of Wisconsin–Madison in 1927. His department was a milestone in establishing anesthesiology

within a university setting. Waters's influence in anesthesiology determined the commitment of this specialty to education and research. Successful application of the Wisconsin model was best reflected by the work of Waters's academic descendants, such as Emery Rovenstine at New York's Bellevue Hospital and Robert Dripps at the University of Pennsylvania.

Modern anesthesiology practice

Although advances were made in the early 1900s, including Sir Robert Macintosh's and Sir Ivan Magill's contributions to airway management, the modern practice of anesthesiology evolved in the latter half of the 20th century with an emphasis on safety. In 1985, the Anesthesia Patient Safety Foundation was established with a mission "to ensure that no patient is harmed by anesthesia." The introduction of additional monitoring tools, such as capnometry and pulse oximetry, remarkably decreased mortality rates during anesthesia. The refinements in current anesthesia delivery systems would have been unimaginable for anesthesiologists of yesteryear.

Today, the practice of anesthesiology in the United States depends on guidelines provided by the American Society of Anesthesiologists (ASA). The stated goals of this professional organization are to establish "an educational, research and scientific association of physicians organized to raise and maintain the standards of anesthesiology and to improve the care of patients."

The history of anesthesiology is vast and complex; this chapter is meant to serve as a brief overview. The best repository for documents and artifacts relating to the history of anesthesia is the Wood Library–Museum at ASA headquarters in Park Ridge, Illinois.

Suggested readings

Bigelow HJ. Insensibility during surgical operations produced by inhalation. *Boston Med Surg J* 1846; 35:309–317.

Ellis T, Narr B, Bacon D. Developing a specialty: J.S. Lundy's three major contributions to anesthesiology. *J Clin Anesth* 2004; 16:226–229.

Frolich MA, Caton D. Pioneers in epidural needle design. *Anesth Analg* 2001; 93:215–220.

Greene NM. Anesthesia and the development of surgery (1846–1896). *Anesth Analg* 1979; 58:5–12.

Griffith HR, Johnson GE. The use of curare in general anesthesia. *Anesthesiology* 1942; 3:418–420.

Keys TE. Paracelsus, 1493–1541. *Anesth Analg* 1972; 51:533.

Knapp H. Cocaine and its use in ophthalmic and general surgery. *Arch Ophthamol Dec* 1834; 1–5.

Lyons AS, Petrucelli RJ. *Medicine: An Illustrated History*. New York: Abradale Press; 1978:530.

McIntyre AR. Historical background, early use and development of muscle relaxants. *Anesthesiology* 1959; 20:409–415.

Ortega RA, Kelly LR, Yee MK, Lewis, KP. Written in Granite: A history of the ether monument and its significance for anesthesiology. *Anesthesiology* 2006; 105: 838–842.

Pierce EC. Anesthesia monitoring guidelines: their origin and development. *ASA Newsletter Sept* 2002; vol. 66(9).

Waters RM. Pioneering in anesthesiology. *Postgrad Med* 1948; 4:265–270.

Waters RM. Why the professional anesthetist? *Journal-Lancet* 1919; 39:32–34.

Waters RM, Hathaway HR, Cassels WH. The relation of anesthesiology to medical education. *JAMA* 1939; 112: 1667–1671.

Part 1

Preoperative Care and Evaluation

B. Scott Segal and Angela M. Bader, editors

Chapter 2

Preoperative anesthetic assessment

Sohail K. Mahboobi and Sheila R. Barnett

The preoperative assessment is a vital part of any procedure requiring anesthesia. The assessment itself may vary considerably, from a simple interview and limited physical examination on the day of surgery to an extensive medical evaluation including invasive cardiac testing and radiologic examinations weeks in advance of the surgery. The choice and type of the preoperative assessment depend on several variables, including the patient's age and medical history as well as the type and degree of risk of procedure planned. Patient and physician preferences should also be considered.

The preoperative assessment

Preoperative assessment provides an evaluation of the patient's anesthetic risk from the proposed procedure and allows recommendations to be made that may minimize risk and ensure a smooth transition from surgical booking to the operating room and beyond. Recommendations may include further testing, consultations, adjustments of medication, or simply reassurance and a consequent reduction of anxiety. Practically, the preoperative assessment may also identify special needs, such as the need for a latex-free environment, special blood products, interpreters, or airway equipment. Failure to plan for these needs may lead to surgical delays. In addition, instructions for fasting and medications, as well as expectations for the day of surgery and postoperative course, should all be provided (Fig. 2.1).

A preoperative assessment should include a medical history focusing on active medical issues, medication usage and past anesthetic and surgical experiences, a limited physical examination, an airway assessment, and additional testing as indicated. The anesthetic risk is derived from the knowledge of the patient and the surgery. The preoperative interview should include a discussion with the patient about the risks and benefits of different anesthetic techniques. Informed consent for anesthesia administration should be obtained. There are several alternative approaches to preoperative assessment (primary physician clearance, telephone interview, preoperative health survey, Internet health quiz), and the choice depends on hospital resources and the type of surgical facility.

The preoperative history

The preoperative history includes a thorough systematic review of the patient's medical problems, including an evaluation of available medical information. Organ systems and selected disorders that have particular impact preoperatively are briefly reviewed, highlighting major issues that should be covered in the course of a preoperative assessment.

Cardiovascular system

Cardiovascular complications may result in significant morbidity and mortality, and a thorough preoperative assessment of cardiovascular status should be part of any routine preoperative evaluation. Questions should be directed at assessing the status of current cardiac problems and eliciting evidence suggesting occult cardiac disease. A complete cardiovascular history also includes assessment of functional capacity (Table 2.1) and ascertains whether symptoms that may indicate significant

Figure 2.1. Goals of preoperative assessment

Table 2.1. Functional assessment scale

1 MET	Can you take care of yourself? Eat dress, use the toilet? Walk indoors around the house? Walk 1–2 blocks on level ground at 2–3 mph? Do light housework?
4 MET	Climb a flight of stairs? Carry groceries? Walk on level ground at 4 mph? Run a short distance? Do heavy housework? Do moderate sports – golf, dance, doubles tennis?
10 MET	Play competitive sports? Play singles tennis? Ski?

cardiac disease are present. Details about past cardiac events and testing should be requested and reviewed. Past electrocardiograms (ECGs) are critical to obtain in patients found to have an abnormal ECG.

Functional capacity

Functional capacity may be assessed from a careful history in the form of metabolic equivalents. The *metabolic equivalent of task (MET)*, or simply *metabolic equivalent*, is a physiologic concept expressing the energy cost of physical activities as multiples of resting metabolic rate. MET is defined as the ratio of metabolic rate (and therefore the rate of energy consumption) during a specific physical activity to a reference metabolic rate at rest, set by convention to 3.5 ml O_2/kg/min or equivalently, 1 kcal (or 4.184 kJ)/kg/h. By convention, 1 MET is considered the resting metabolic rate obtained during quiet sitting. Patients unable to meet a 4-MET standard are at increased risk for perioperative cardiac risk. Daily activities, such as eating, dressing, walking around the house, and dishwashing, range from 1 to 4 METs. Climbing one flight of stairs, walking on level ground at about 6 km/h, running a short distance, or playing a game of golf range from 4 to 10 METs. Playing tennis, swimming, and playing football exceed 10 METs. This is helpful in assessing cardiac risk and planning preoperative testing (Table 2.1).

The decision to send a patient for further cardiac evaluation is complex and includes consideration of patient comorbidities as well as the level of risk of the planned procedure. The guidelines written by the American College of Cardiology (ACC) and the American Heart Association (AHA) have updated recently and provide excellent algorithms for guidance in this regard along with various levels of evidence (Table 2.2, Fig. 2.2). Briefly, emergent surgical procedures may not allow further cardiac assessment or treatment. In this case only perioperative medical management and recommendations are required. The patients who are having nonemergency procedures should be evaluated for the presence of active cardiac conditions (Table 2.3). The presence of any of these active cardiac conditions warrants further evaluation prior to procedures of even the lowest risk. If none of these active conditions exists, the patient's functional status should then be assessed.

According to these guidelines, if the patient's functional status is good (>4 MET), even higher-risk procedures (Table 2.4) may be undertaken without further cardiac noninvasive testing. If the functional status is inadequate or cannot be obtained, the presence of five clinical risk factors, as defined by these guidelines, should be ascertained. These clinical risk factors include a history of ischemic cardiac disease, a history of compensated or prior heart failure, diabetes, renal insufficiency, and cerebrovascular disease (Table 2.5). If three or more of these factors are present, and vascular or higher-risk procedures are being contemplated, further cardiac noninvasive testing may be warranted if it is felt this will affect management. Table 2.6 summarizes recommendations for noninvasive stress testing before noncardiac surgery.

Adequate β-blockade should be established perioperatively, if indicated. The recommendations are same for the patients with one or more risk factors going for high-risk vascular or intermediate risk surgery. Patients with no risk factors can proceed with the planned procedure. According to the AHA/ACC guidelines only two groups should be mandated for β-blockade: vascular patients with recent positive provocative cardiac testing (based on Poldermans 1999) and patients already taking β-blockers. Other than that, β blockers are probably recommended for intermediate risk or vascular surgical procedures with the presence of more than one clinical risk factor. Their usefulness is uncertain for patients with no or one risk factor and not already on β blockers. Similarly, patients already receiving calcium channel blockers should continue these medications, including on the day of surgery. Patients taking statins should continue doing so because this has been linked to fewer perioperative cardiac events and improved outcome, presumably by modulating inflammatory pathways. The optimal time for initiation and duration of perioperative statin therapy remains unclear.

There are significant numbers of patients with a history of percutaneous coronary intervention (PCI) in the form

Table 2.2. Levels of evidence

Class I	**Class IIa**	**Class IIb**	**Class III**
Benefit >>> risk Procedure/ treatment should be performed/ administered	Benefit >> risk Additional studies required It is reasonable to perform procedure/ administer treatment	Benefit ≥ risk Additional studies required Procedure/ treatment may be considered	Risk ≥ benefit No additional studies needed Procedure/ treatment should not be performed/ administered because it is not helpful and may be harmful

Table 2.3. Active cardiac conditions as defined by ACC/AHA 2007 guidelines

- Unstable coronary syndromes
  - Unstable or severe angina
  - May include stable angina in unusually sedentary patients
  - Recent myocardial infarction (within 30 d)
- Decompensated heart failure, worsening or new-onset heart failure
- Significant arrhythmias
  - Mobitz II atrioventricular block
  - Third-degree atrioventricular block
  - Symptomatic ventricular arrhythmias
  - Supraventricular arrhythmias with uncontrolled ventricular rate
  - Symptomatic bradycardia
- Severe valvular disease
  - Severe aortic stenosis (mean pressure gradient > 40 mm Hg, aortic valve area < 1.0 cm^2, or symptomatic)
  - Symptomatic mitral stenosis

Table 2.4. Cardiac risk for noncardiac surgery

High risk (>5%)	Intermediate risk (<5%)	Low risk (<1%)
Emergency	Carotid endarterectomy	Endoscopic surgeries
Aortic and major vascular	Head and neck	Superficial procedures
Peripheral vascular	Intraperitoneal and intrathoracic	Cataract surgery
Lengthy procedures with major blood loss or fluid shifts	Orthopedic	Breast procedures
	Prostate	

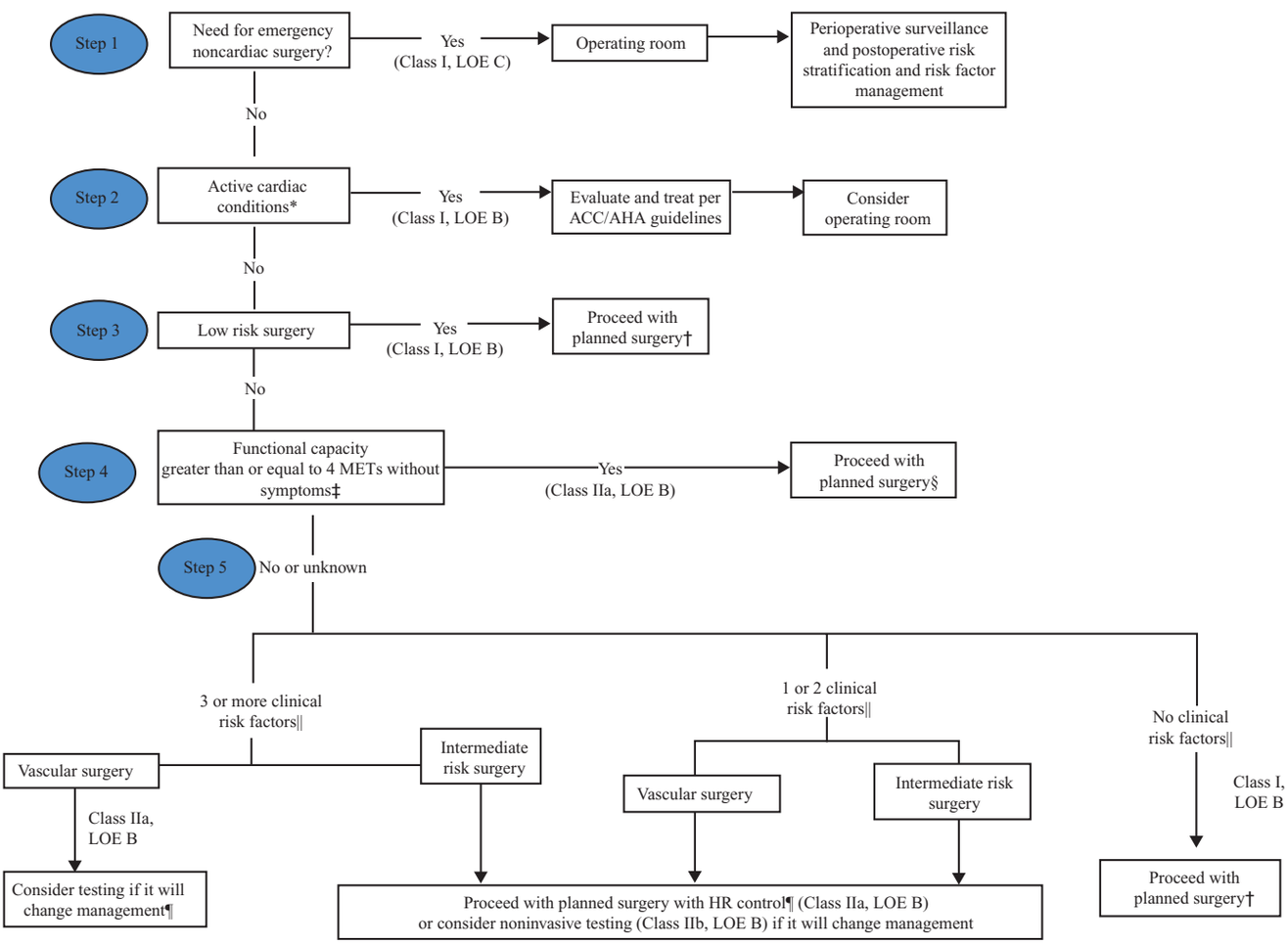

Figure 2.2. Cardiac evaluation and care algorithm for noncardiac surgery based on active clinical conditions, known cardiovascular disease, or cardiac risk factors for patients ≥ 50 years of age. *See Table 2.3 for active clinical conditions. †See class III recommendations in Table 2.6, Noninvasive Stress Testing. ‡See Table 2.1 for estimated MET level equivalent. §Noninvasive testing may be considered before surgery in specific patients with risk factors if it will change management. ‖Clinical risk factors include ischemic heart disease, compensated or prior heart failure, diabetes mellitus, renal insufficiency, and cerebrovascular disease. Consider perioperative β-blockade for populations in which this has been shown to reduce cardiac morbidity/mortality. HR, heart rate; LOE, level of evidence. (Modified from Fleisher LA, et al. ACC/AHA 2007 Guidelines on Perioperative Cardiovascular Evaluation and Care for Noncardiac Surgery: Executive Summary: A Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. *Circulation* 2007; 116:1971–1996.)

Table 2.5. Patient clinical risk predictors

Clinical risk factors (formerly known as intermediate risk factors)	Minor risk predictors (have not been proven to increase perioperative risk independently)
History of ischemic heart disease	Advanced age
History of compensated or prior HF	Abnormal ECG
Diabetes mellitus	• LV hypertrophy
Renal insufficiency	• Left bundle-branch block
History of cerebrovascular disease	• ST-T abnormalities
	Rhythm other than sinus
	Uncontrolled systemic hypertension

MI, myocardial ischemia; HF, heart failure.

Table 2.6. Recommendations for noninvasive stress testing before noncardiac surgery

Class I	Patients with active cardiac conditions in whom noncardiac surgery is planned should be evaluated and treated per ACC/AHA guidelines before noncardiac surgery
Class IIa	Noninvasive stress testing of patients with 3 or more clinical risk factors and poor functional capacity (less than 4 METs) who require vascular surgery is reasonable if it will change management
Class IIb	Noninvasive stress testing may be considered for patients with at least 1 to 2 clinical risk factors and poor functional capacity (less than 4 METs) who require intermediate-risk or vascular surgery if it will change management.
Class III	• Noninvasive testing is not useful for patients with no clinical factors undergoing intermediate-risk noncardiac surgery • Noninvasive testing is not useful for patients undergoing low-risk noncardiac surgery

of balloon angioplasty, bare metal stents (BMS) or drug-eluting stents (DES). These patients require antiplatelet therapy to avoid thrombosis. According to AHA/ACC recommendations at least four weeks of antiplatelet therapy (clopidogrel) is required for patients with BMS and 12 months of dual antiplatelet therapy (aspirin and clopidogrel) is required for patients with DES. Surgeries during this period of antiplatelet therapy pose a serious challenge. Recommendations are to delay the planned surgical procedures for at least 14 days after balloon angioplasty, 30 to 45 days after BMS placement and 365 days after DES placement. After these periods one can proceed to the operating room with continuation of aspirin (Figure 2.3).

A history of hypertension is common, affecting more than 50% of adult Americans. The preoperative assessment in a patient with hypertension should elicit any history of end-organ disease. Ischemia, myocardial infarction, diastolic dysfunction, renal failure, and cerebrovascular disease all may be consequences of untreated hypertension. Although blood pressure should optimally be controlled at the time of the preoperative visit, the literature suggests there are no absolute contraindications based on systolic or diastolic values that necessitate cancellation of an elective procedure. If a patient is seen in the preoperative clinic with poorly controlled hypertension and enough time exists before the procedure, the primary care physician should be contacted to attempt to achieve better medical management.

Pulmonary disease

Chronic pulmonary conditions may increase the risk of postoperative respiratory failure. History taking in patients with chronic obstructive pulmonary disease or asthma should include questions about the type of disease, duration, therapy, and baseline condition. Recent interventions, such as hospitalization, intubation, or changes in medications, such as the addition of steroids or antibiotics, should be documented. Patents may need a steroid pulse prior to surgery, require antibiotics for an acute bacterial process, or they may need arrangements for postoperative chest physiotherapy. Current symptoms may restrict the choice of anesthetic options; for instance, a case

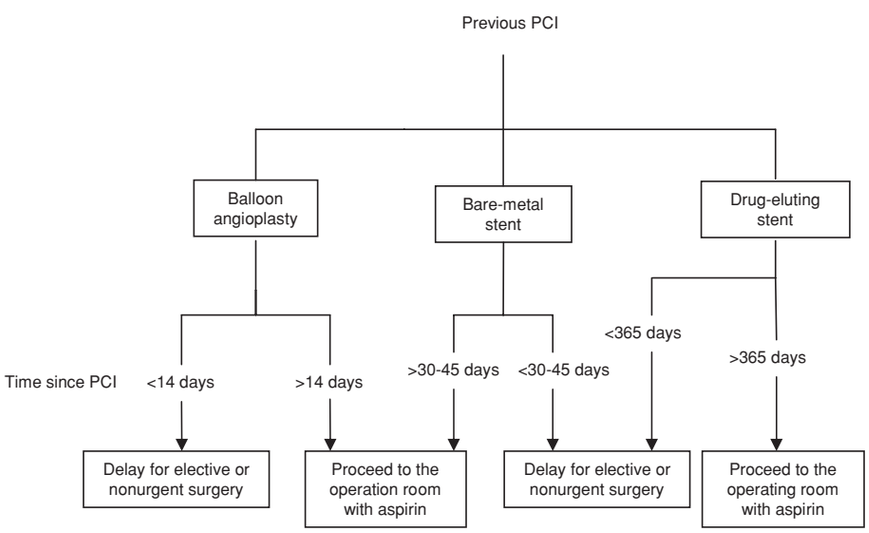

Figure 2.3. Proposed approach to the management of patients with previous percutaneous coronary intervention (PCI) who require non-cardiac surgery. (Modified from Fleisher LA, et al. ACC/AHA 2007 Guidelines on Perioperative Cardiovascular Evaluation and Care for Noncardiac Surgery: Executive Summary: A Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. *Circulation* 2007; 116:1971–1996.)