



# PRINCIPLES OF ANESTHESIOLOGY

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## PREFACE

A quarter of a century has elapsed since the writing of *Principles and Practices of Anesthesiology*. That first edition was ambitious in that all aspects of the scope of anesthesiology were encompassed in basic form in one book. As stated in 1950 by Dr. Ralph Tovell, Director of the Department of Anesthesiology at Hartford Hospital in Connecticut and former Chief of Anesthesiology for the U.S. Armed Forces in the European Theatre of Operations World War II, the text provided a fundamental background, a source of reference and "a treatise broad enough in scope to provide students, residents in anesthesia, and anesthesiologists with information not found in any other single text."

The concept of a single volume with single authorship and a basic integrated overview of the field were the guidelines in preparation. It was conceded not to be exhaustive but in some measure a concise, comprehensive and documented text. The scope of anesthesia was considered to cover eight phases: (1) Clinical Fundamentals, (2) Regional Anesthesia, (3) Physiologic and (4) Pharmacologic Considerations, (5) Special Problems of Management of Surgical Procedures and

of Disease States, (6) Complications—Anesthetic and Postoperative, (7) Blood and Intravenous Therapy and, (8) Respiratory (inhalation) Therapy.

A second edition was to be published in 1966, still under single authorship. However, the burgeoning of information, the tremendous productivity and the pursuit of knowledge by young men in a young specialty made the task of single authorship a monumental one and the product in a single volume impossible. Consequently, it was decided that two volumes—one a text on Principles and the other on Practices—would be the feasible plan. *Principles of Anesthesiology*, appearing in 1966, encompassed four phases: Fundamentals, Regional Anesthesia, Physiologic and Pharmacologic Considerations. This left four other aspects to be covered in another volume. This second volume in preparation will be entitled *Practices in Anesthesiology*. It will be written by multiple authors and it is hoped to be an integrated body of information with minimal duplication. The plan is complete but the construction is slow, again because of enormous advances in the specialty limiting the available time of one individual to achieve the original goals.



## viii Preface

Meanwhile, this second edition of *Principles of Anesthesiology* is presented to the reader for his use and reference. It is hoped that it will meet present needs in Clinical Anesthesia. I recognize that selection of material on the basis of permanent and practical value is a vast challenge. Such practices from the literature. Uncertainties, controversial issues and esoteric facts were generally excluded. Concepts of proven value, both scientific and humanitarian; factual information supported by research; and technics which have stood the test of time have been included. The literature and specialized texts have been important sources for material, but personal communications with colleagues and friends have been of equal value.

The text has been developed for the use of students and of specialists. It has been an edifying experience for me; it is hoped the reader will find it so.

Thanks are due to many for encouragement, criticism and assistance. Courtesies are extended appropriately throughout the text. Special mention must be made of the following: Anis Baraka of American University of Beirut, Lebanon for his help on muscle relaxants; Julius Comroe of Cardiovascular Research Institute, University of California in San Francisco, for his kindness in providing illustrations and material for Respiratory Physiology; Kurt Jacobs, Director of Anesthesia Research in Hektoen Institute and Cook County Hospital, Chicago, for his assistance in preparing chapters on cardiovascular physiology; Beverly Britt of Univer-

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In the Department of Anesthesiology of Cook County Hospital, M. Ramez Salem, Moustafa El-Naggar, Mahalingam Mathrubutham, Bahman Venus, Alphonso Wong, Edward Bennett, and Murugiah Mani have been patient and constructive critics while Orlando Cuasay has been an able proof-reader. Many have provided secretarial assistance and have been most patient under trying circumstances. To them my unbounded thanks.

For deficiencies and errors I take responsibility. Apologies are offered to the astute and discerning reader for shortcomings herein. Your indulgence is requested in the words of the Seneca Indian prayer:

"Grant that I may not criticise my neighbor until I have walked for a moon in his moccasins."

Chicago, Illinois

Vincent J. Collins

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# SECTION I

## FUNDAMENTAL PRACTICES

### Chapter

## THE HISTORY OF ANESTHESIOLOGY

*The Man Who Does Not Heed the Past is Doomed to Repeat It.*

—PROVERB.

In man's struggle to survive, perhaps his greatest and indeed his constant battle is against physical pain. The story is a dramatic one, and the present state of achievement in the control of pain is a culmination of many disheartening experiments and isolated triumphs. Men have made this story. To understand pain control and anesthesia, we are obligated therefore, to report the contributions of men, and we will follow the history of anesthesia in terms of many men of vision and of courage.<sup>1</sup>

Prior to 1842, an operative procedure was a struggle for the surgeon and an ordeal for the patient. The most important attribute of the surgeon was not his skill, but his speed. Numerous agents had been used with the purpose of relieving pain, but all were attended with minimal success.

### ANESTHESIA IN ANTIQUITY

At the beginning of historic time man is found seeking means to dull the morbid, and

even lethal edge of pain. In the dark ages, memorable battles against pain were fought without much success. The first attempts at deadening human pain began with the use of the poppy, the māndragora, the hyoscyamus, and alcohol.<sup>2</sup> A sponge impregnated with a preparation of opium, henbane and mandrake was known as the "soporific sponge," and employed by Hippocrates and Galen. It was used to produce inhalant anesthesia. When actually tested it was found not to "even make a guinea pig nod." One can well imagine the witchcraft and quackery associated with the preparation of "soothing brews" most of which had little scientific value.

We know that the Greeks used infusions of herbs and various drugs to induce sleep as recounted in Homer's *Odyssey*. One can speculate on the ingredients of such infusions. Perhaps the lotus, which hypnotized with Lethæan forgetfulness the navigators of *Odysseus*, was part of the potion. The lotus

referred to here is probably the fruit of the African jujube, or the nettletree of southern Europe.

**The Poppy.** The occasion when the poppy was first employed as a means to alleviate pain is lost in the mists of time. The people of Asia were certainly among the first to use concoctions to relieve pain, and opium constituted the basic ingredient. In addition, "hashish" was used for centuries by oriental peoples to produce euphoria, forgetfulness, and inebriation.

**Tears of Poppy.** The drips of sap exuding from scratches on the unripe seed pod was actually opium. It was known to many as an effective drug. Dioscorides, Galen, Pare, Celsus, and others have mentioned opium and recognized narcotic action. Celsus was especially interested in providing sleep. Among his several formulas for anesthesia is the following pill containing poppy:

Those pills which alleviate pain by causing sleep are called anodynes in Greek. It is bad practice to employ them except in cases of urgent necessity, for they were compounded of powerful drugs and are bad for the stomach. However, one may be used, which contains a denarius (about 3i) each of tears of poppy and galbanum, and two denarii each of myrrh, castoreum, and pepper. It is enough to swallow a piece of the size of a bean.

**Hyoscyamus.** In the fifth century before Christ, the physicians of Cos and Cretona used many and varied medicinal substances, and actually had a pharmacological classification of drugs, according to their effects. One group, the refrigerants, was considered to be soporific or narcotic. They were named *frigidi*, *frigidores* and *frigidissimi*, according to their intensity. (It was considered that relief of pain or suffering was the result of "cooling".) Hyoscyamus was called *herba frigidissimi*—it was quite effective; wild lettuce was only slightly effective.

The seeds of hyoscyamus were used to eliminate pain. Dioscorides well knew its actions and its poisonous effect. It was used to catch mice, to catch birds and to produce sleep. Celsus, the surgeon, used a concoction

to relieve toothache and to provide a sleepy, forgetful patient for his surgery. Generally, in most potions, hyoscyamus was combined with opium, and Celsus had several formulas containing both.

**Mandragora.** The third most popular drug of antiquity was mandragora. It was especially favored by the Romans as a surgical anesthetic, and was mentioned by Pliny. The rind of the root was preferred, and its potency well recognized. Dioscorides wrote of mandragora—

"It is an herb whose rind mixed with wine, is given to drink, to those whose cure must be surgical, so that they will fall asleep and feel no pain. . . ."

At the famed University of Bologna, in the early 13th century came the Dominican friar Theodoric of Lucca (1205-98). He was known for his surgery and his admonitions. In surgery, he advocated the use of sponges drenched with a narcotic or mandragora which were applied to the patient's nose; cutting was not to begin until the patient was asleep.

It should be noted that priority in the usage of the word *anesthesia* in its modern connotation belongs to Dioscorides. In describing the effects of mandragora the word was used exactly as it would be today.<sup>2</sup>

**Alcohol.** For centuries alcoholic preparations were employed prior to operations and to the reduction of dislocations and fractures. Wine was a favorite. Only when given in large quantities was there material relief of pain. In the eighteenth and nineteenth centuries it was rather popular. Usually, the patient drank quantities of the beverage until a stuporous state was reached, whereupon the surgeon proceeded. Dr. Philip Syng Physick of Philadelphia (1768-1837) recommended the use of intoxicating amounts of alcoholic preparations for the purpose of relaxing muscles before manipulating fractures.

**Strange Methods of Anesthesia.** One strange method of pain relief for surgery was that of strangulation, used by the Assyrians for circumcision of their children. The

asphyxia and attendant unconsciousness obviously relieved the pain of the moment and allowed the surgeon to proceed with his operation. Anesthesia by strangulation to point of unconsciousness was practiced in Italy as late as the seventeenth century. Another method was that of cerebral concussion, achieved by placing a wooden bowl over the head of the patient, and striking this until the patient became unconscious. The directions were simple: Strike the bowl with sufficient strength to crack an almond but leave the skull intact.

Some diminished pain by the application of intense cold or compression of the nerve roots. Such methods were used by the Romans, apparently learned from the Assyrian monks. Revived in 1700 by Moore, it was used in Italy by Ruggieri.

### PRECURSORS

As we approach the year 1800, study on the chemistry of gases was firing the work of many men. J. Black in 1750 studied carbon dioxide which he called "fixed air." Cavendish identified hydrogen in 1776 and described it as "inflammable air." In this period Lavoisier discovered both nitrogen and oxygen. Rutherford called nitrogen "phlogisticated air." Then, in 1774, Joseph Priestley prepared oxygen which he called "dephlogisticated air" and in 1776 he discovered nitrous oxide. In these findings lay some hope for man in his struggle to alleviate pain. To explore the possibilities, other men with imagination were needed and they soon appeared.

**A Founder: Sir Thomas Beddoes** (1760–1808). Beddoes began the study of the action of gases on man in Bristol. In collaboration with James Watt he published a work entitled, "Considerations on the Medicinal Use and Production of Factitious Airs." He founded the famous Pneumatic Institute in Clifton, England. In the annex to the laboratory, sick people were treated with various gases. Oxygen was especially popular, but the expectations were too great and the venture fell into disrepute. It is note-

worthy too, that Beddoes published a case report of deep sleep produced by ether.

**Discovery: Humphrey Davy.** In 1799 this young man was placed in charge of Beddoes' laboratory and instructed to do research on the action of carbon dioxide and nitrous oxide. Both animals and men were used for these experiments.

He wrote a book on his work and had it published under the title of *Researches, Chemical and Philosophical—Chiefly Concerning Nitrous Oxide and Respiration*. In it are described methods of obtaining the gas, and the effects of the gas on human beings, the subjects included Davy and many of his distinguished visitors. The central effects were readily appreciated, especially the pleasant inebriation and the associated relief of pain. Because of the exhilarating property of nitrous oxide he called the substance "laughing gas." The practical possibilities of his discoveries were recognized, and he wrote:

As nitrous oxide . . . appears capable of destroying physical pain, it may probably be used to advantage during surgical operations in which no great effusion of blood takes place." This statement went unheeded.

**Obscurity: Henry Hickman.** A young English doctor from Ludlow was driven by the terrors of the operating room to seek a remedy for pain. Henry Hill Hickman pursued further the researches of Davy and in 1824 successfully anesthetized animals placed under bell-jars with a mixture of nitrous oxide and oxygen. The animals remained unconscious long enough to have amputations performed, and most important, they recovered. These results were published in a book on suspended animation.

However, Hickman was opposed in his desire to try the gases on human beings. In 1828 he demonstrated his experiments before the French Academy. Only Baron Larrey recognized the possibilities and offered himself as a subject, but even his enthusiasm was dampened by the general skepticism. Hickman was soon discouraged and returned to England to die within a few months.



**Michael Faraday.** In 1818, Faraday wrote about the stupefying effects of ether. He noted that when the vapor of ether was mixed with air, it produced effects similar to nitrous oxide. Physicians were familiar especially in America with these effects in producing inebriation and sleep.

Although the drug was considered dangerous in medical practice, nevertheless it was safe enough to be used by medical students for "kicks" at their parties. These ether frolics were called "jags" and were attended by many, including Crawford Long.

**Mesmerism.** A strange chapter in the story of anesthesia is the use of hypnotism.<sup>3</sup> Operations have been performed painlessly during mesmeric trances—and are being performed today. In 1779, Friedrich A. Mesmer of Vienna startled the world by publishing his "pretensions concerning animal magnetism" and by demonstrating his capacity to bring certain subjects under hypnotic influence. It appears that the first surgical procedure under mesmerism was performed by J. Cloquet, a French surgeon in 1829. In England, mesmerism as a medical tool was introduced and popularized by John Elliotson, the physiologist. At his demonstrations many famous men were observers, including Charles Dickens and Thomas Moore. He used the technic to manage epilepsy, and other medical problems as well as to provide pain relief. Elliotson gave lectures on the subject at University College Hospital. His advocacy during the period 1830–1840 aroused strong resentment among his rivals.

In the meantime, James Esdaile (from Perth, England) in charge of the Native Hospital in Hooghly, India, read of Elliotson's activities and was inspired to try mesmerism on a surgical case. The results encouraged him to try the technic on others and he reported 73 operations in 1846 done under hypnosis.

But a new star was in the ascendancy. Opposition to mesmerism on philosophical grounds was one thing, but competition with a more effective method was another. Mesmerism failed because it was less efficient than

ether and chloroform. An advocate of mesmerism commented "that the more tangible agents, ether and its fellows, possess one advantage, namely, that of superior certainty." Furthermore, the process was time consuming and not suited to surgery. In another hundred years, however, its proper niche in the field of anesthesia would be found (See Chapter 37, Hypnosis).

### THE ETHER CONTROVERSY

The discovery of surgical anesthesia is an American contribution and has been called America's greatest contribution to medicine. The significance of this discovery is of such a nature, however, that it may more aptly be called one of the greatest contributions to mankind. At the semi-centennial anniversary of the discovery of ether, Weir Mitchell the poet-physician wrote as follows:

Whatever triumphs still shall hold the mind,  
Whatever gift shall yet enrich mankind,  
Ah! here no hour shall strike through all the years,  
No hour as sweet, as when hope, doubt, and fears,  
'Mid deepening stillness, watched one eager brain,  
With Godlike will, decree the Death of pain.

Events in the period 1842 to 1846 were the culmination of a long series of experiments and frustrations, of researches and discoveries.<sup>10</sup> About discoveries in every sphere one always asks two questions: How long must the world wait to be convinced? What event triggers the universal acceptance of an idea? Three men particularly lay claim to discovery of surgical anesthesia. Only one gets the full credit; nevertheless, all in their attempts to gain contemporary recognition ended in some tragedy or met a violent fate, and with their character tarnished.<sup>4</sup>

**The Dentist—Horace Wells.** In Hartford, Connecticut, a dentist, Horace Wells attended a side-show in which Colton, the chemist, demonstrated the exhilarating effects of nitrous oxide. A subject accidentally injured his shins but he did not cry out nor did he recall having any pain. Wells was so impressed by the insensibility produced by the gas that he decided to use it in dental

extractions. On December 10, 1844, another dentist, Dr. Riggs painlessly extracted a tooth from Wells who was under the influence of nitrous oxide.

Wells continued to use the agent in his practice and became well-known for his painless dentistry. Eventually, he was invited to demonstrate his work before a group of colleagues at the Massachusetts General Hospital in Boston for a major surgical operation. In his enthusiasm, Wells failed to realize the pharmacologic nature of nitrous oxide and the demonstration was a failure. Ridicule followed and the agent fell into disrepute. Wells became deranged and an ether addict. Later, he committed suicide in a New York City prison cell by cutting his cubital vein while his arm was in a hot water bath. An ironic touch to the suicide act was the simultaneous inhalation of the vapor of ether. Perhaps to relieve the pain of the incision?

**First Use—Long.** In his youth, Crawford W. Long first witnessed the effects of ether at "frolics" in Philadelphia. He came to appreciate the possibilities of ether in surgery. In January, 1842, he administered the vapors of ether to James Venable in Jefferson, Georgia. The method was successful and a large tumor was removed from the patient's neck. Thereafter, he used the method often for minor surgery. Long's use of ether threw the neighborhood of Jefferson into excitement and the population threatened to lynch him. He, therefore, abandoned operations under ether and even removed his offices to Athens, Georgia. He never became acutely involved in the vexatious disputes about priority and was the only character in the controversy to escape real tragedy. Furthermore, his work received little recognition until publicized by Marion Sims. Long has been honored by a statue in the Statuary Hall in Washington, D. C. The inscription written by men of strong belief reads, "Discoverer of the use of sulphuric ether as an anesthetic in surgery on March 30th, 1842, at Jefferson, Jackson County, Georgia."

A curious sequel to his first use of ether occurred in Texas. Dr. George Pascal relates

that a practicing physician in San Antonio by name, George Venable, recently removed a tumor from the arm of a Mrs. Long who was under ether anesthesia. Each was a descendent of the original parties to the use of ether, but the roles were reversed in this later episode.

**First Demonstration—Morton.** Born in Charleston, Mass., William T. G. Morton had the consuming ambition to be a physician. His father could not afford the schooling, so William entered dentistry. He began his practice in Farmington, Connecticut, and while there became acquainted with Wells. The two aspired to open an office in Boston, but Wells was discouraged and only Morton persisted and established a good practice. But he was inwardly driven to seek a means for alleviating the pain of dental operations and at this juncture he decided to undertake his medical studies at Harvard.

Meanwhile, he consulted with Professor Charles J. Jackson and learned that sulphuric ether had some effect in producing unconsciousness. Morton then experimented upon his dog, on fish, on himself and his friends, and finally extracted a tooth painlessly under ether.

As a second-year medical student, he then secured permission from Dr. John Collins Warren, the professor of surgery at Harvard to make a public trial of ether for a major operation. The demonstration was set for October 16, the year was 1846. It was the turning point in the history of anesthesia.

The event was brief but dramatic and world shaking. Morton was late because he was developing an inhaler (Fig. 1-2). Nevertheless, he arrived in the amphitheater of Massachusetts General Hospital, now the ether dome, and proceeded to anesthetize Gilbert Abbott. When the patient was unconscious Morton said to Dr. Warren, "Sir, your patient is ready." The operation proceeded quietly, there was no struggle or screaming. At the conclusion of the operation, Warren turned to the audience and said, "Gentlemen, this is no humbug." And Dr. Henry J. Bigelow, an eminent surgeon,

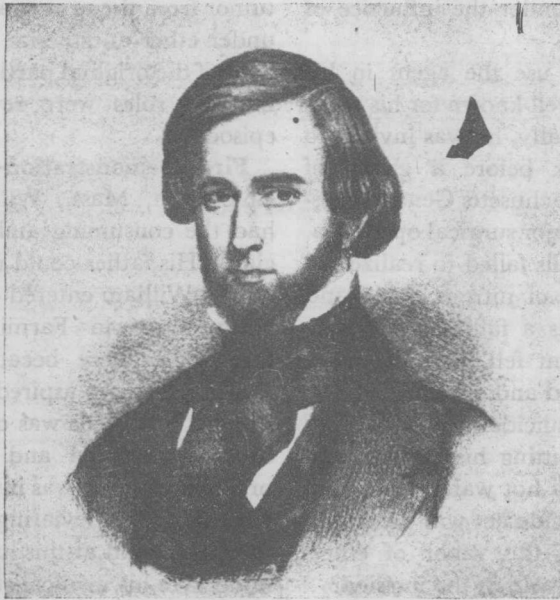


FIG. 1-1. Wm. T. G. Morton. (From The Yale Medical Library. Permission of Dr. John F. Fulton: as compiled in *An Annotated Catalogue of Books and Pamphlets Bearing on Early History of Surgical Anesthesia*. Henry Schuman, N.Y., 1946.)

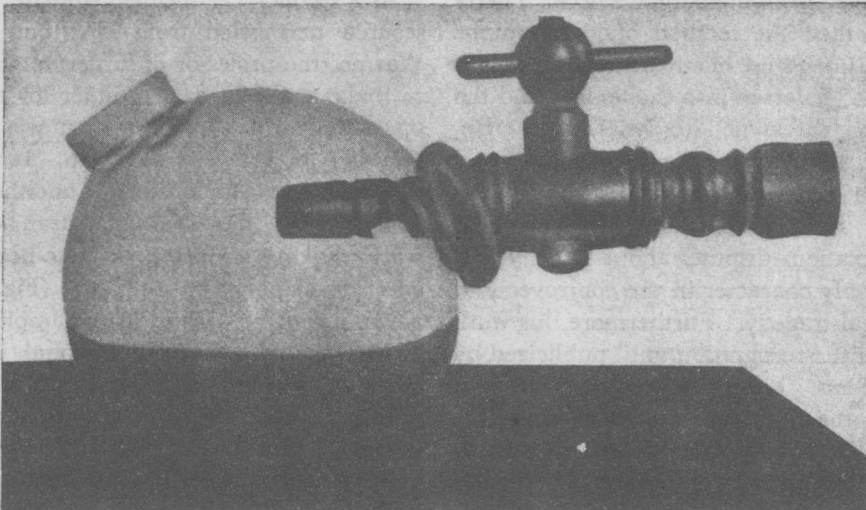


FIG. 1-2. The original Morton inhaler, with which operations were performed at Massachusetts General Hospital. (From *Triumph Over Pain* by René Fülöp-Miller, The Bobbs-Merrill Co., New York, 1938.)



declared, "I have seen something today which will go around the world." In fact, Bigelow's father helped to promote world-wide knowledge of the event for, in a letter to Dr. Bott of London the following month, he inspired the English surgeons to attempt the same. The earliest printed reference of the first demonstration appeared in Boston Daily Journal on October 17th. The Bigelow paper of November 18, 1846 was the original medical announcement.

These, and other papers and communications, serve to establish the undoubted claim of Morton to the title of Discoverer of Surgical Anesthesia. Following Morton's demonstration of the effectiveness and comparative harmlessness of ether anesthesia, the practice was generally accepted. Prior to this, "the profession had never dared to use ether in this way," but Morton's youthful recklessness and disregard for the status quo convinced the world (Fulton) and the idea became sustained practice.

Morton went through many trials and hardships thereafter. He was maligned by the public. He was ridiculed one day and honored the next. He was on the verge of wealth, but really poverty-stricken. He was the subject of a Congressional inquiry and even denoted as the "Benefactor of Mankind." President Pierce was about to settle the controversy when he wavered on a technicality. Only in two circumstances did Morton appear content and happy—one was as a farmer on his place in Needham, Mass.; the other as a physician administering anesthesia to soldiers of the Union Army.

Dr. Oliver Wendell Holmes suggested the word "anesthesia," and in a letter to Morton said, "I think this state should be called anesthesia. This signifies insensibility, more particularly to objects of touch." Holmes did not coin the word—it had already been used by Greek philosophers and had appeared in Bailey's English Dictionary in 1721.<sup>6</sup>

After the Civil War, Morton returned to Massachusetts. But one day he received a copy of an article written by Jackson in a

monthly magazine. It was full of hatred and claimed that Morton had nothing to do with the discovery of ether. He was enraged and suffered a mild stroke, but he sufficiently recovered to go to New York City to refute the article. Summer had come to the City and on July 15th it was a furnace, especially the Riverside Hotel where Morton was staying. So he drove through Central Park in the evening to steady his nerves. Part way through, he grew giddy and weak. Then, just before the carriage reached the Park gates he reined up the horses, jumped to the ground and soon fell unconscious in his wife's arms beneath a tree. He was taken to St. Luke's Hospital and there died of his apoplexy. Peace had come at last. Though rejected in 1868, his place in history is secure forever.

In all this controversy, only the reflection of later generations can distinguish values. The point of history is not who was first but rather who helped to integrate an idea into acceptable medical practice.

**The Others.** Crawford W. Long served as a physician with the Confederate forces. After Appomattox, he was a ruined man, ever plagued by "ifs" and disappointment. One evening he went to deliver a farmer's wife and while inducing ether anesthesia, he fell across the patient's bed—dead.

Consuming jealousy and unrequited hate ended Jackson's career. After Morton's death, he continued his efforts to discredit him, but death has a way of immortalizing men. It was impossible to answer every reference to Morton, the discoverer. Bitterness was drowned in whiskey. One afternoon he wandered to the Mount Auburn Cemetery and caught sight of the inspiring monument erected by the citizens of Boston to Morton. On reading the inscription, he became enraged and thenceforth was a frenzied maniac. He was committed to a lunatic asylum and died there in 1880.

The inscription read by Jackson on Morton's memorial is simple and true.