# Handbook of Critical Care Neurology and Neurosurgery

*Edited by*

Robert J. Henning, M.D., FACP, FCCP, FACC
David L. Jackson, M.D., Ph.D.

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# Introduction

During the past twenty years the practice of critical care neurology and neurosurgery has evolved in parallel with remarkable advances in our understanding of life support biology and technology. The immediate availability of potent resources for transportation, rapid identification, monitoring, and treatment of life-threatening central nervous system illnesses and injuries has profoundly affected the organization of hospital services and the methods of medical practice in hospitals throughout the world. The purpose of the *Handbook of Critical Care Neurology and Neurosurgery* is to serve the practicing physician with a useful, current reference book on accepted techniques available for the diagnosis and treatment of acute nervous system illnesses. A succinct and understandable presentation of applied science is offered to be used in quiet study as well as in the heat of battle in the critical care units. This is not intended to be a mini-textbook of neurology and neurosurgery.

The historical development of critical care neurology and neurosurgery is traced from the early Egyptian treatment of patients with skull fractures due to war injuries in the year 3500 B.C. to the present era of brain computerized transaxial tomography, nuclear magnetic resonance imaging, and intracranial pressure monitoring. Modern technology has significantly enhanced clinical deduction in identifying and localizing many intracranial masses and destructive lesions. The intricacies of the neurological examination of the critically ill and injured patient are discussed with special emphasis on the importance of eye movements, pupillary reflexes, and motor responses to stimulation. The use of brain computerized axial tomography and nuclear magnetic resonance imaging in the diagnosis of patients with subdural and intracerebral hematoma, hemorrhagic infarction, subarachnoid hemorrhage, AV malformation, neoplasms, empyema, and herpes encephalitis is demonstrated. Treatment strategies for acute cerebral ischemia secondary to cardiopulmonary arrest are reported. These include the use of anticoagulants, barbiturates, and calcium channel antagonists in order to improve the central nervous system (CNS) oxygen supply/energy demand ratio. The use of CNS pressure monitoring devices such as the Richmond bolt, the

ventricular catheter, the Wilkinson cup catheter, and the Ladd fiberoptic monitor for measuring intracranial pressure as well as the fundamental techniques of measurement are discussed. Recognizing that acute head injury and cranial cerebral trauma have surpassed stroke in frequency and are the third leading cause of death in the United States, the prognosis for patients with acute brain injury with persistent coma is surveyed in detail. This is extremely important information which directly impacts on the utilization of intensive care resources and the cost of health care. The management of patients with transient ischemic attacks, reversible neurologic deficits, stroke, and subarachnoid hemorrhage is considered. Pharmacologic guidelines are provided for the control of status epilepticus. The complications of alcohol abuse are described in the discussion on Alcohol Related Diseases of the Nervous System. Neuromuscular diseases, which commonly present with acute respiratory failure, and neurogenic pulmonary edema, a complication of CNS crises, are reviewed. Bacterial and viral meningitis, encephalitis, brain abscess, and subdural empyema, which occur in both pediatric and adult patients, are described. Finally, old and new diagnostic criteria for brain death and their implications in the high-technology medical intensive care unit are considered.

The contributions have been organized with both tables and illustrations in order to clarify and emphasize important information. In some instances, there is overlap between subjects and divergent viewpoints that differ from those of other contributors and the editors. It is hoped that such contributions stimulate thought and discussion among the clinician–readers. Deliberate attempts have been made to avoid long bibliographies. The references at the end of each chapter are limited to reviews that contain comprehensive bibliographies as well as to a few of the most significant recent articles. Finally, the contents of the textbook have been carefully indexed to facilitate rapid access to important information required by the clinician.

The editors wish to express their sincere thanks to the associate authors for participating in this venture and to the many house officers and physicians who contributed suggestions and criticisms. In addition, special recognition is due to Mr. Michael Fisher of the Praeger Publishing Company who guided us in the development of the textbook from its inception.

Robert J. Henning
David L. Jackson

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# 1

# The History of Critical Care Neurology and Neurosurgery

*Jeanette C. Hartshorn*

## ANCIENT BEGINNINGS

The earliest accounts of neurosurgical practice are found in ancient Egyptian writings. The Edwin Smith Surgical Papyrus (3500 B.C.), authored by Imhotep, medical advisor to Pharaoh Yoser, is the first surviving document that uses the word "brain." Thirteen cases of skull fractures due to war injuries and descriptions of individuals with skull fractures bleeding from either the nose or ears are found in this record. The Edwin Smith Papyrus indicates that the ancient Egyptian physicians knew of the membranes and convolutions of the brain. They were also aware of the relationship between the side of the brain and side of the body [1]. Representations of neurological disease, such as speech disturbances, are also recorded in the papyrus [2], together with descriptions of limited nursing procedures such as the feeding of patients and the dressing of wounds. Nurses were most probably family members of the injured [1].

Although trephination of skulls was practiced during this time, it originated in prehistoric times. Most trephinated skulls found have one hole, although some have as many as thirteen. Walker [3] suggests that in some primitive tribes the practice of trephination has continued into the present century.

With the decline of Egyptian civilization, medicine came under Greek influence. The Greeks believed that the Olympian gods inflicted or averted diseases at will. Notably, they named gods

such as epilepsy, insanity, and hysteria. Hippocrates, who emerged from this background, has often been called the father of medicine. One of his observations was that a depressed skull fracture could cause paralysis of the contralateral side of the body. He is also credited with an understanding of brain function that differed from his contemporaries, identifying the brain as being the area where

> arises our sorrows, pain, griefs and tears. Through it, in particular, we think, see, hear and distinguish the ugly from the beautiful, the bad from the good, the pleasant from the unpleasant. To consciousness, the brain is the messenger. [4]

Hippocrates developed specific instructions to assist the physician in performing neurosurgical procedures. He wrote that openings should not be made over cranial sutures and, in addition, warned that the temporal region was to be avoided for fear of damaging "the vessel," which might lead to convulsions on the opposite side of the body [3]. Galen (A.D. 131–201), a Greek physician living in Rome, has been called the founder of experimental neurophysiology. Galen differentiated and named several cerebral structures including the dura and pia mater, the corpus callosum, the four ventricles, and the pituitary gland. He also developed a classification of cranial nerves, which was used until the seventeenth century.

Galen served as physician to the gladiators of Pergamon and often observed the effects of injuries to the head and spine. He recognized that injury to the first and second vertebrae caused instantaneous death, while lesions lower in the spinal cord caused bladder and lower limb paralysis. In a description of a patient who had fallen from his chariot, Galen described the differences between sensory and motor function [5].

Until the time of the Renaissance, surgery of the brain was primarily restricted to the treatment of acute injuries and their complications. Following the abolition of bans on human dissection during the Renaissance, the science of anatomy advanced. DaVinci and Vesalius are well known for their contributions throughout this era [6]. In 1504, Leonardo DaVinci produced wax casts of the ventricular system. He drew some of the first diagrams of the cranial nerves, the optic chiasm, and the brachial and lumbar plexus. DaVinci also showed the mechanism of action of antagonistic muscle groups.

Vesalius, who served as Army Surgeon to Charles V, is credited with developing anatomy as a science. Vesalius developed anatomical illustrations that were reproduced as woodcuts and

copper plates. With the availability of printing, more rapid dissemination of knowledge became possible. In 1560, Johann Dryander published the first work on the anatomy of the head and brain.

Thomas Willis (1621–75), professor of natural philosophy of Oxford, published the *Cerebri Anatomie* in 1664, which described the arteries at the base of the brain, now called the Circle of Willis. Although the vascular circle had been observed by others, Willis demonstrated the existence of blood vessels within the substance of the brain by injecting solutions of dark-colored dye into peripheral vessels and noting the appearance of dark spots on the cut surface of the brain. Willis also classified the cranial nerves into nine pairs and distinguished cranial, spinal, peripheral, and autonomic nerves from the brain and spinal cord [7,8].

Development of surgical procedures throughout this time was retarded by the lack of adequate anesthesia. Cannabis, opium, and wine were used but did not produce acceptable levels of anesthesia [9].

Nursing practice during the Middle Ages and Renaissance was strongly influenced by religious communities. Nurses were protected within the religious groups and were hired to "make beds, wash and attend the poor patients," for which they were paid a small salary. The chief duties of a nurse were to take care of the physical needs of the patients. Under these conditions, women described as "drunks, thieves and those with no place to go" were attracted to nursing [10]. Dressings were applied by dressers or surgeons; the dispensing of medicine was the responsibility of the doctors and the apothecary [11].

## THE EIGHTEENTH CENTURY

The eighteenth century was the age of formal theories and systems in medicine. Physicians practiced with individualized theories and sometimes utilized secret remedies. Some advances, however, did occur. William Heberden (1710–1801) described epilepsy, palsy, apoplexy, madness, tremors, and St. Vitus' dance [2].

Felix Vica d'Azyr (1748–94), the permanent secretary to the Paris Academy of Medicine and personal physician to Marie Antoinette, produced an atlas of colored plates of the brain and nervous system in 1786. His major discovery was that dissections of the brain were facilitated by first hardening the brain in alcohol.

## THE NINETEENTH CENTURY

The nineteenth century was initially marked by an elaboration by many scientists of the internal structures of the body and gross anatomy of the nervous system. A hallmark of development during this period was increased personal communication. Physicians evaluated new clinical problems by receiving input from colleagues from all over the world [2]. Neurosurgery was the direct outgrowth of three fundamental discoveries of the nineteenth century—"anesthesia, asepsis, and accuracy" (i.e. cerebral localization) [12].

Early cerebral localization studies were attempted by Franz Joseph Gall and Johann Casper Spurzheim. Gall noted that some individuals with certain intellectual qualities had interesting cranial prominences. Based on these observations, he and Spurzheim developed the theory of phrenology, which stated that there were 40 separate organs believed to control the moral, intellectual and sexual traits of each individual. The strength of each trait was proportional to the size of each organ, and if the area was developed, a lump in the skull could be palpated in that area [13]. Although always controversial, phrenology was discredited by the middle of the century.

Sir Charles Scott Sherrington (1856–1952), one of the most outstanding and versatile neurophysiologists of the nineteenth century, described motor and sensory segmentation and sensory dermatones and demonstrated decerebrate rigidity in monkeys and the stretch reflex. Golgi studied the neuron during this era. The first textbook of neurology was written by Heinrich Romberg in 1820 [14]. This work included his classic description of the Romberg sign.

John Hughlings Jackson (1835–1911), the father of English neurology [15], observed the characteristic progression of focal motor seizures. He surmised that there must be a topographical motor representation of body parts within the cerebral hemispheres. Jackson introduced the clinical use of the ophthalmoscope and was one of the founders of the journal *Brain* in 1872 [16].

The first clinical neurology service began with Jean Martin Charcot (1825–93). Charcot established separate divisions of opthalmoscopy, microscopic work, photography, and anatomy. His ability to demonstrate various tics and tremors in order to teach others formed an important part of his contributions [17]. In addition, Charcot developed a detailed study of the phases of epilepsy.

The French surgeon Pierre Broca (1861) demonstrated from autopsy studies in two patients that a small circumscribed lesion in

the left posterior third frontal convolution caused a profound speech disturbance. Precise cerebral localization in the human brain began as a separate discipline during this time.

Victor Horsely, who practiced at the end of the nineteenth century, is considered the father of neurosurgery because of his primary interest in and important contributions to diseases of the nervous system [18]. Horsely's contributions included surgery for the treatment of epilepsy and the performance of a laminectomy for removal of a spinal cord tumor. By 1891, Horsely had developed a technique to expose the pituitary gland and an operation on the posterior root of the trigeminal nerve to alleviate the pain of tic douloureux. Additional contributions included his studies on localization within the cerebral cortex and cerebellum [9].

During the nineteenth century, the practice of neurology and neurosurgery grew in the United States. William Alexander Hammond assisted in the development of neurology in the army during the Civil War [19]. In 1863, he ordered the establishment of the U.S. Army hospital for diseases of the nervous system and, in 1871, published the first American textbook of neurology. Hammond established the first department of neurology in 1871 at the University of Pennsylvania.

Another leader of American neurology was Weir Mitchell. Toward the end of the Civil War, Mitchell and his colleagues, in a military hospital in Philadelphia, began studies of nerve injuries. Following the war, Mitchell continued his interest in neurological practice and became one of the most respected neurologists of the era.

The American Neurological Association was founded in 1875, with its goal as "the cultivation of Neurological Science in its normal and pathological relations." Weir Mitchell was elected the first president [20].

Although great strides in neurological and neurosurgical care were made during the nineteenth century, some undesirable practices flourished. Most afflictions of the nervous system were treated as syphilitic; consequently, patients with brain tumors were rubbed with mercury, often until their eyesight failed. Accordingly, patients often were poor surgical risks and died before surgery. Neurosurgery was performed by a few general surgeons who developed special interests in the nervous system. Surgery on the posterior fossa for cerebellar abscesses was initiated in the late nineteenth century [3]. Surgery was aided by Sir Humphrey Davy, who noted that the use of nitrous oxide produced a state of "insensibility," thereby easing the work of the surgeon [2]. Another major discovery of the nineteenth century, which aided the growth

of medical practice, was Roentgen's demonstration that x-rays could penetrate soft tissues readily, but bone poorly. This discovery led to the development of radiology.

Nursing became established as a separate discipline during this century, largely due to the efforts of Florence Nightingale. A well-educated and dedicated person, Nightingale gained a worldwide reputation because of her improvements in hospital care during the Crimean War. As a result of the procedures that she instituted, the mortality rates caused by infections and malnutrition were greatly reduced. In 1869, the Nightingale Training School for Nurses was established, with the philosophy that "good nursing does not grow of itself, it is the result of study, training, practice and ending in sound tradition which can be transferred elsewhere" [21].

During the later half of the nineteenth century, nurses in England and France became involved in specialized care of the patient with neurological dysfunction. In London, nurses observed Horsely's first operation at the National Hospital [22], and this hospital rapidly became a well-known and respected center for neurological care. Nursing education occurred informally as physicians shared their knowledge with nurses. An organized course in neurological nursing was not offered at the London Hospital until 1949.

In the United States, schools based on the Nightingale model were established, training nurses to work as generalists. Students provided care for patients from 5:30 a.m. until 9:00 p.m., with a free afternoon from 2:00 to 5:00 p.m. every two weeks. Notable personalities of this age include Linda Richards, the first graduate of an American nursing school, and Mary Mahoney, the first black nurse. Educational programs contained mostly practice, with only 2% of the curriculum concerned with theory. Even with this, many physicians felt that nurses were overtrained. One Harvard physician wrote that "serious mental exercise would damage a woman's brain or cause other severe trauma, such as the narrowing of the pelvic area, which would make her unable to deliver children" [23].

Neurological nursing emerged as a subspecialty during the later part of the nineteenth century. Charles Karsner Miller (1845–1931) began lecturing to nurses on the care of the patient with neurological disease at the Philadelphia General Hospital. In 1889, the content of this course was presented in a book, *The Nursing and Care of the Nervous and Insane.* Most probably, this is the first neurological nursing textbook. In the preface, Dr. Mills writes: "In no class of cases is it more important for a nurse,

caretaker or companion to have good principles of action and clear notions of practice, than among patients suffering from nervous or mental afflictions" [24].

## THE TWENTIETH CENTURY

Harvey Cushing (1869–1939) is one of the best-known figures from this era and is often credited with guiding the growing profession of neurosurgery during its formative years. Among his most notable contributions were studies on the circulation of cerebrospinal fluid, description of the "Cushing Phenomena," and the classification of tumors, which was published in 1932. Cushing is also recognized for his contributions to cerebral localization [25–28].

Use of intravenous anesthetic agents such as Sodium Pentothal began in World War I. Overall treatment of craniocerebral trauma improved during both the first and second world wars with the increased availability of anesthetic drugs and antibiotics. Nurses were actively recruited into the armed forces during both wars and were sent overseas to work in war zone hospitals. An account of the experiences of one nurse reminds one of the intensity of the situation:

> Here is an unconscious lad with head completely bandaged. The gauze is stiff with blood and dirt. I cut carefully and removed it, glad he is unconscious; much easier to work when they cannot feel pain. As the last band comes off, a sickening mass spills out of the wide gash at the side of his skull. Brains. I am stunned. I cannot think what to do. No time to ask questions. Everyone around me is occupied with similar problems. Boldly I wrap my hand in sterile gauze and thrust the slippery mass back as best I can, holding the wound closed while I awkwardly tie a clean bandage around the head. It does not occur to me until afterwards that he must have been dead. [29]

During this era (1900–20), special wards designated for the care of patients with neurological illness were established. The New York Neurological Institute was founded in 1909 by Joseph Collins, Pearce Bailey, and Joseph Fraenkel. This facility was used for the treatment of military personnel with injuries and diseases of the nervous system from World War I [20]. Dr. Charles Elsberg was appointed chief surgeon of the Institute. Among the objectives of

the founders was the "training and education of physicians and nurses in the interpretation and treatment of nervous diseases."

Amy Hilliard became the first superintendent of nurses in the New York Neurological Institute in 1910. Miss Hilliard is credited with organizing the first postgraduate nursing course in the care of patients with nervous system diseases.

Miss Gertrude Dwyer succeeded Miss Hilliard as Superintendent of Nurses at the New York Institute in 1916. In 1920, she published "Nursing Care Following Operations on Spinal Cord and the Brain" in the *American Journal of Nursing* [30]. Dwyer stressed that nurses should study the anatomy and physiology of the brain and spinal cord and should have good general surgical training before specializing in this field.

Technological advances continued throughout this period. In 1910, Cushing first used the transphenoidal surgical approach. By 1920, neurological surgery encompassed the treatment of brain and spinal injuries and tumors, peripheral nerve injuries, and intractable pain. Moriz, in 1927, developed the first angiogram, and Berger, in 1919, published reports on brain waves. The Society of Neurological Surgeons was formed in Boston in 1920, with Harvey Cushing as the first president. Since the specialty of neurological surgery grew faster than this society, a second group was formed in 1932, "The Harvey Cushing Society." This organization developed the *Journal of Neurosurgery*, which began publication in 1944.

The care of casualties with neurological dysfunction during World War II was slightly improved over that in World War I. Early in 1942, the neuropsychiatric branch of the Office of the Surgeon General of the Army was elevated to division status, on a level with the divisions of medicine and surgery. With this change, neurology became one of the four branches of the office. Neurosurgical care also began to change. Specialty units for the treatment of peripheral nerve, spinal cord, and brain injuries were established in the European theater and continental United States [20].

Nurses were heavily involved in World War II. With recruitment of nurses into the military, civilian hospitals began to experience acute shortages. Alternative systems for the delivery of nursing care, such as functional and team nursing, were designed to deal with the limited numbers of professional nurses [11].

In 1951, the government established the National Institute of Neurological Diseases and Blindness [31]. The purpose of this organization was "to provide training and instruction and establish and maintain traineeships and fellowships in matters relating to