History of spine surgery in the ancient and medieval worlds

JAMES TAIT GOODRICH, M.D., PH.D.
Leo Davidoff Department of Neurological Surgery, Albert Einstein College of Medicine, Children’s Hospital of Montefiore, Bronx, New York

There is a paucity of surviving texts from ancient and medieval times that can shed light on the early development of spine surgery. Nevertheless, the author reviews many of the available books and fragments and discusses early developments in the field of spine surgery from the point of view of physicians’ personalities, general themes, and actual surgical practices. For purposes of an overview and to highlight changing trends in spine surgery, he divides the paper into four eras of medicine: 1) Egyptian and Babylonian; 2) Greek and early Byzantine; 3) Arabic; and 4) medieval.

EGYPTIAN AND BABYLONIAN MEDICINE: THE EMBRYONIC PERIOD

The Egyptian period encompasses approximately 30 successive dynasties and holds the claim to have produced the earliest known practicing physician, Imhotep, who lived in the 14th century BC. For the modern scholar interested in studying medical and surgical material from this epoch, there are only three existing documents that deal with the development of spine surgery in ancient and medieval worlds. For purposes of an overview and to highlight the changing trends in spine surgery over the entire period, I have divided this paper into the following eras: 1) Egyptian and Babylonian medicine, the embryonic period; 2) Greek and early Byzantine medicine, the historical origins of spine surgery; 3) Arabic medicine, the prescholastic period; and 4) medieval medicine, the period of medical scholasticism.

For the ancient physician, the fear of operating was a real one, especially when one had to deal with the central nervous system. Two centuries before the birth of Christ, King Hammurabi of Babylon (1955–1912 BC) introduced a set of equitable laws that dealt with matters of everyday life such as marriage, slavery, land purchase, and, of course, medicine. The penalties established in this codex for making surgical errors led surgeons in that period to approach patients with some trepidation. In Hammurabi’s Code there are nine paragraphs devoted to the physician; one in particular deals with the operator who carries a bronze knife (scalpel) for wound care:

If a physician makes a wound and cures a freeman, he shall receive ten pieces of silver, but only five if the patient is the son of a plebeian or two if he is a slave. However it is decreed that if a physician treats a patient “with a metal knife for a severe wound and has caused the man to die—his hands shall be cut off” (Code of Hammurabi).

In this paper I will discuss early developments in the field of spine surgery from the point of view of personalities, themes, and actual surgical practice as revealed in literature surviving from ancient and medieval worlds. For purposes of an overview and to highlight the changing trends in spine surgery over the entire period, I have divided this paper into the following eras: 1) Egyptian and Babylonian medicine, the embryonic period; 2) Greek and early Byzantine medicine, the historical origins of spine surgery; 3) Arabic medicine, the prescholastic period; and 4) medieval medicine, the period of medical scholasticism.
The Edwin Smith papyrus, written after 1700 BC, during the time of the New Kingdom, is considered to be the oldest book on surgery per se; it comprises a papyrus scroll measuring 15 ft in length and 1 ft in width. A total of 48 cases are discussed in this document, including ones in which there were injuries to the spine and cranium. Each case includes a diagnosis followed by a formulated prognosis. Owing to the scholarly work of James Breasted, this papyrus has been translated from the original, which is in the possession of the New York Historical Society, and has been published in a limited edition. Aside from isolated cases found in these remaining papyri fragments, little can be gleaned from them on the actual practice of surgery and, in particular surgery of the spine. Rather than a direct surgical approach, most authors argued for stabilization and allowing nature to run its course. It is evident from these writings that the Egyptian physician recognized spine injury to be a most serious problem with an outcome that was almost always fatal. In this section I will review several cases detailed in the Edwin Smith Papyrus that deal with spine injury.

Edwin Smith has variously been described as an adventurer, money lender, dealer and forger of antiquities, pioneer in the study of Egyptian science, and a man of “great intellectual gifts.” In 1862 Smith, while in Luxor, acquired the papyrus under controversial circumstances. Although some scholars believe that Smith legitimately purchased the scroll from an Egyptian businessman named Mustafa Agha, others claim that he bought it illegally from unscrupulous tomb raiders. Regardless of the methods by which he obtained the manuscript, Smith recognized its importance and made efforts toward a first translation. The papyrus remained in Smith’s possession until his death in 1906, after which his daughter donated it to the New York Historical Society. No further inquiry was made into the secrets of the papyrus until 24 years later when it was “rediscovered” and turned over to James Henry Breasted, an American Egyptologist and archeologist.

Although the papyrus reveals ancient Egyptian knowledge about the heart and its relationship to the pulse, as well as functions of the stomach, bowels, and vascular system, the majority of the cases in the text concern topics of neurosurgical interest. It is not surprising, therefore, that some of the oldest descriptions of the brain, cerebrospinal fluid, meninges, skull, and cranial sutures can be found in the Edwin Smith papyrus. In addition to direct observations of trauma and anatomy, Egyptian scholars appear to have been surprisingly observant, as shown when they discuss the relationship between injuries of the brain and spinal cord and their functional consequences in other parts of the body.

The following cases are reproduced from Breasted’s 1930 classic translation.

Case Twenty-Nine: A gaping wound in a cervical vertebra.
If thou examinest a man having a gaping wound in a vertebra of his neck, penetrating to the bone, [and] perforating a vertebra of his neck; if thou examinest that wound, [and] he shudders exceedingly, and he is unable to look at his two shoulders and his breast [conclusion follows in diagnosis].

Diagnosis: Thou shouldst say concerning him: “One having a wound in his neck, penetrating to the bone, perforating a vertebra of his neck, and he suffers with stiffness in his neck. An ailment with which I will contend.”

Treatment: Thou shouldst bind it with fresh meat the first day. Now afterward moor [him] at his mooring stakes until the period of his injury passes by.

Case Thirty: Sprain in a cervical vertebra. Examination: If thou examinest a man having a sprain in a vertebra of his neck, thou shouldst say to him: “look at thy two shoulders and thy breast.” When he does so, the seeing possible to him is painful.

Diagnosis: Thou shouldst say concerning him: “One having a sprain in a vertebra of his neck. An ailment which I will treat.”

Treatment: Thou shouldst bind it with fresh meat the first day. Now afterward thou shouldst treat with honey every day until he recovers.

Case Thirty-One: Dislocation of a cervical vertebra.
Examination: If thou examinest a man having a dislocation in a vertebra of his neck, shouldst thou find him unconscious of his two arms and his two legs on account of it, while his phallus is erected on account of it, and urine drops from his member without his knowing it; his flesh has received wind; his two eyes are bloodshot; it is a dislocation of a vertebra of his neck extending to his backbone which causes him to be unconscious of his two arms and his two legs. If, however, the middle vertebra of his neck is dislocated, it is an emissio seminis which befalls his phallus.

Diagnosis: Thou Shouldst say Concerning Him: “One having a dislocation in a vertebra of his neck, while he is unconscious of his two legs and his two arms, and his urine dribbles. An ailment not to be treated.”

Case Thirty-three: A crushed vertebra in his neck.
Examination: If thou examinest a man having a crushed vertebra in his neck and thou findest that one vertebra has fallen into the next one, while he is voiceless and cannot speak; his falling head downward has caused that one vertebra crush into the next one; and shouldst thou find that he is unconscious of his two arms and his two legs because of it. (Conclusion follows in diagnosis).

Diagnosis: Thou Shouldst say Concerning Him: “One having a crushed vertebra in his neck; he is unconscious of his two arms (and) his two legs, (and) he is speechless. An ailment not to be treated.”

Case 48: A sprain of a spinal vertebra (incomplete).
Examination: If thou examinest (a man having) a sprain in a vertebra of his spinal column, thou shouldst say to him: “Extend now thy two legs (and) contract them both again.” When he extends them both he contracts them both immediately because of the pain he causes in the vertebra of his spinal column in which he suffers.

Diagnosis: Thou shouldst say concerning him: “One having a sprain in a vertebra of his spinal column. An ailment which I will treat.”

Treatment: Thou shouldst place him prostrate on his back.

The Edwin Smith papyrus is undoubtedly one of the most significant early medical texts ever discovered. Although valuable to the scientific and nonscientific world, because of its antiquity and general relevance as the earliest medical text, the papyrus is of particular interest and value to neurosurgeons because of its specific references to ancient neurosurgical cases. The descriptions of both brain and spinal cord traumas and infections, as well as the recommended treatments, would assuredly be applicable to the general population in ancient Egyptian times. The Edwin Smith Papyrus provides modern neurosurgeons with a window in time through which they can wonder at the challenges and insights faced by ancient Egyptian healers at the dawn of the medical profession.
History of spine surgery

GREEK AND EARLY BYZANTINE PERIOD: THE HISTORICAL ORIGINS OF SPINE SURGERY

Hippocratic School

The intellectual evolution of neurological spine surgery originated in the golden age of Greece with the founding of the Alexandrian School in 300 BC (Fig. 1). It was then that open dissection was incorporated into formal teaching, providing in a significant step forward. During the Greek period there was not yet any conception of a surgeon who, in the strict sense, restricted himself to the practice of “neurosurgery” or to surgery only of the spine. Spine and head injuries, however, appear to have been plentiful, owing to wars and internecine conflicts (as graphically recorded by the historians, Herodotus and Thucydides, if not also by Homer). War was then, and still remains, the primary source of material for the study and treatment of neurosurgical injuries.

In the Iliad Homer describes Achilles’ actions after he had dispensed a fatal blow to his foe:

Achilles, smiting him with the sword upon his neck, hurled afar his head and therewithal his helmet; and the marrow spurted forth from the spine and the corpse lay stretched upon the ground.

Homer continues in a further passage:

...and Hector with his sharp spear struck Eioneus on the neck below the well-made helmet of bronze, and loosed his limbs.

The earliest medical writings from this period are generally thought to be those of Hippocrates (460–370 BC), the most celebrated of the Asclepiadae. Raised in an Asclepiad family, Hippocrates could trace his ancestry through 15 generations directly to Asclepius. Classical philologists believe that many of the writings attributed to Hippocrates, were in reality, composed by members of the Hippocratic School. The Hippocratic collection presents clinical cases based on observation, but only the simplest of theories are offered. The concept of a disease arising from an organic system was little understood, and disturbances in “humors” or in certain fluids in the body were prominent in the elementary Greek view of illness.

The Hippocratic writings contain numerous anatomical descriptions, even though human dissection was not routinely practiced. One particular drawback for the contemporary reader of these writings was their lack of graphic illustration, compelling the reader to visualize and memorize his own “picture” of the anatomical description. Another lay in the fact that the Greeks had no anatomical vocabulary at that time; this would not be introduced until Galen made use of the Latin language. These deficiencies combined to retard any standardized anatomical procedures or the practice of surgery. Despite these drawbacks, within the Hippocratic writings, there are a number of interesting histories that do reflect the early practice of spine injuries.

A review of Hippocratic texts suggests that actual surgery on the spine was a great rarity. Stabilization of the spine with external splinting was common. Injury to the spinal marrow was believed to be quite serious and resultant problems with urinary retention were considered to be indicators of the gravity of the injury. Hippocrates wrote about such an injury and laments the presence of charlatans who would offer cures that were spurious at best.

And the spinal marrow would suffer, if from the displacement of a vertebra if were to be bent even to a small extent; for the displaced vertebra would compress the spinal marrow, if it did not break; and if compressed and strangled, it would induce insensibility of many great and important parts, so that the physician need not to give himself any concern about rectifying the displacement of the vertebra, accompanied, as it is, by many other ill consequences of a serious nature. It is evident, then, that such a case could not be reduced either by succession or by any other method, unless one were to cut open the patient, and then, having introduced the hand into one of the great cavities, were to push outward from within, which one might do on the dead body, but not all on the living. Wherefore, then, do I write all this? Because certain persons fancy that they have cured patients in whom the vertebra had undergone complete dislocation forward. Some, indeed, suppose that this is the easiest of all these dislocations to be recovered from, and that such cases do not stand in need of reduction, but get well spontaneously. Many are ignorant, and profit by their ignorance, for they obtain credit from those about them.

From this brief clinical note one can see that Hippocrates and his school clearly did not favor surgical intervention (Fig. 2). External stabilization and immobilization remained the treatment of choice. Besides the expected poor outcomes, there was still the risk of infection, the lack of an antiseptic technique, and minimal anesthesia that kept the Hippocratic school and subsequent generations of surgeons from following any form of aggressive surgical intervention in spine injury.

Herophilus of Chalcedon (ca. 300 BC)

From the region of the Bosphorus, among the crowded schools of Alexandria came Herophilus of Chalcedon, a pupil of Praxagoras and Chrysippus and a member of the educated dynasty of the Ptolemies. Unlike his predecessors, Herophilus performed dissection on humans—more than 100, according to his own account—but not on animals. He also engaged in the arduous task of developing an anatomical nomenclature and creating a much needed language for anatomy. In examining the nervous
Celsus was neither a physician nor a surgeon, but rather an intellectual patrician and a medical encyclopedist. His writings had an important early influence on surgery and treated the spine. He recognized that injuries of the spinal column and, particularly, to those of the spine marrow were invariably lethal or, at the very least, carried a dismal prognosis. He agreed, therefore, that direct surgical invention on the spinal column should be avoided.

Aulus (Aurelius) Cornelius Celsus (25 BC–AD 50)

Celsus was neither a physician nor a surgeon, but rather an intellectual patrician and a medical encyclopedist. His writings had an important early influence on surgery and he also examined the three contemporary rival medical schools: dogmatic, methodic, and empiric. These writings remain a valuable summary of the healing art for this period. As counselor to the emperors Tiberius and Caligula, Celsus was held in great esteem. His book, De Re Medicina, was considered one of the most important early medical documents after the Hippocratic writings. Because for a time his work was lost, he was one of the few major authors not to be transcribed by the Arabists. It was not until 1443, when an early Celsus manuscript was uncovered by Thomas Sarazanne (later Pope Nicolas V) that Celsus’ work could be reintroduced to the medical community. With the introduction of moveable type, this work became the first medical manuscript to be printed in 1478. Indeed, its publication antedated the printing of works by Hippocrates and Galen. In Book 4, Chapter 10 of De Re Medicina we find his classic description of inflammation: notae vero inflammationes sunt quattuor; rubor, et tumor, cum calore et dolore.

In the field of neurosurgery Celsus made a number of interesting early observations. The one most relevant to this paper was his recognition that a cervical spine fracture could lead to vomiting and difficulty in breathing, and not uncommonly to death. Injury to the lower spine, on the other hand, he demonstrated could cause weakness or paralysis of the leg, as well as urinary retention or incontinence. Again following earlier Hippocratic views, Celsus did not recommend surgical intervention but, rather immobilization and stabilization as the key to recovery. Once urinary incontinence or retention occurred he believed that the situation had become quite grave.

Galen of Pergamon (129–200)

Galen of Pergamon, whose name is derived from “galeenos,” which means calm or peaceful, is actually remembered as a contentious and often bitter controversialist. Nevertheless, this powerful personality was an original investigator, compiler, and codifier, as well as a leading proponent of the doctrines of Hippocrates and the Alexandrian school. Galen began writing at the age of 13 years and continued to do so until he died at the age of 70 years. His collection of writings overwhelmed the ancient world with its size, scope, and influence. Even if we were to eliminate the writings of the Corpus Hippocraticum, Galen’s prodigious output would still represent more than 80% of all surviving medical writings of antiquity. The modern edition of his work comprises 22 thick octavo volumes.

Galen had the good fortune to live during the reigns of two of the greatest emperors, Antonius Pius (136–161) and Marcus Aurelius (161–180). While he was physician to the gladiators of Pergamon Galen had access to a plethora of human material, particularly patients requiring attention to traumatic injuries. His surgical activities together with his scientific studies enabled him to make a wide range of contributions to neuroanatomy and neurosurgery. Among the anatomical experiments he performed was the transection of the spinal cord, which led him to describe loss of function below the level of the lesion. In the dog and pig Galen sectioned the recurrent laryngeal nerve and recognized that hoarseness was a consequence. A review of the existent literature shows that he made the attempt to identify and number the cranial nerves, of which he demonstrated 11 of the 12; by combining sever al of these nerves, he arrived at a total of only seven. Galen discarded Hippocrates’ notion that the brain is only a gland, and attributed to it instead the powers of voluntary action and sensation, information that was carried through the spinal cord. This observation was a considerable conceptual advance in medicine.

In neurology, too, Galen made a number of critical observations. He recognized that an upper cervical injury can produce a disturbance in arm function. Transecting the spinal cord at C-2 or higher caused a total loss of sensation and motor control from the arms downward.
to the middle or lower cervical spine was demonstrated by a series of cord transections, with results such as paralysis of the chest muscles noted. Galen is remembered for coining the words “kyphosis, lordosis, and scoliosis.” He was among the first physicians to describe Pott disease of the spine and to attribute it to caries in the spine from tuberculosis. He also introduced the “blow bottle” for breathing and lung exercises, and advocated loud singing in an effort to encourage deep breathing and a good pulmonary toilet in the treatment of spine injuries. In a study of spinal cord injury, in particular, he detailed a classic case of what today is known as Brown–Séquard syndrome, that is, a hemiplegia with a contralateral sensory loss in a patient in whom there is hemisection of the cord.\textsuperscript{19} As a result of his vast surgical experience Galen was much more liberal in advocating surgery than his contemporaries: he offered arguments for elevation of depressed skull fractures, fractures with hematomas, and comminuted fractures, and also recommended the removal of bone fragments, particularly those pressing into the brain and spine.

Historically, the Greek and later Byzantine world accepted Galen’s authority without reservation, conferring the status of medical dogma to his writings. After Galen’s death there came the demise of any further anatomical investigation of the nervous system. Equally unfortunate was the lack of any followers or imitators to carry on his work; for all practical purposes ancient science ceased altogether after he died. Nonetheless Galen was held in extremely high esteem by later writers and was almost canonized by Arabic and medieval physicians. Generally speaking, his anatomical studies were well thought out and he made a number of new discoveries. As can happen in any investigative science, several errors crept into his work (for example, rete mirabile), which took time to correct. Approximately 13 centuries elapsed before many of these errors, which had been carefully repeated by subsequent Arabic and medieval physicians and scribes, were finally rectified. The perpetuation of such mistakes had a stultifying effect on new anatomical studies, which were not again seriously undertaken until the Renaissance.

Paul of Aegineta (625–690)

Paul of Aegineta, who was trained in the Alexandrian school, was the last of the great Byzantine physicians. He was an influential compiler of works in both the Latin and Greek schools, and his writings continued to be consulted well into the 17th century. His skill as a surgeon, moreover, drew patients from far away. Although Paul venerated the teachings of ancient scholars as tradition required, he also introduced his own methods with good results. His classic work, \textit{Seven Books of Paulus of Aegineta},\textsuperscript{35} contains an excellent section on head and spine injury (Figs. 3 and 4).\textsuperscript{34} Paul classified skull fractures into several categories: fissure, incision, expression, depression, and arched fractures.

Several of Paul’s earlier manuscripts have survived, in which we can find a number of instruments that he designed for neurosurgical procedures: elevators, raspatories, and bone biters all originated in this period. Important to the views presented here was his early endorsement of spine surgery in cases of spine lamina fractures. In those cases in which the surgeon thought there might be a laminar fracture with cord compression, Paul argued that a decompression (that is, a laminectomy) was in the best interest of the patient. He was the earliest surgeon to do so on a routine basis. In addition to his skills in surgical management, Paul’s views on wound management were also quite sophisticated; he made use of wine (which is helpful in antisepsis, although this concept was unknown at the time) and he stressed the abstention of compression when dressings were applied to the brain and spine.

The Greek and early Byzantine periods proved to be an era of scholarship and original investigation, and produced a group of physicians who were intensely interested in the better treatment of their patients. As we have seen, individuals such as Galen of Pergamon, Paul of Aegineta, Herophilus, and members of the Hippocratic
school all attempted to improve the management of spine injuries and, at the same time, develop a better understanding of spine function. Unfortunately, as we shall observe in the following section, in the prescholastic period of the Arabic and late Byzantine era, neurological investigation and the development of new surgical techniques all but came to a halt. Throughout the medieval period, the treatment of spine injury was considered all but hopeless.

**ARABIC MEDICINE, THE PRESCHOLASTIC PERIOD**

After the great Greek and Roman periods of medicine, the intellectual centers of the discipline shifted to the Arabic and Byzantine cultures, whose major influence was paramount from approximately AD 750 until 1200. Europe at this time was to remain intellectually quiescent and unimaginative, now that it was overrun and ruled by “barbarians” (Huns, Goths, and Norsemen). This was a dormant period in surgery and, in particular, in neuro- and spine surgery. Rather than develop new ideas for medical and surgical treatment, the Arabic schools were satisfied with codifying manuscripts surviving from the Greek and Roman period. Because of the almost incredible zeal of Arabic scholars, the best of Greek medicine was made available to Arabic readers by the end of the ninth century. Unfortunately, a rigid scholastic dogmatism became characteristic of Arabic learning centers, as copyists of the great works of antiquities carried out their translations from Latin, Greek, and Hebrew into Arabic and then systemized the knowledge. Such copyists, too frequently added their own favorite view of the author and subject, sometimes forgetting the correct sense of the original writing. In fairness, however, the Arabs did preserve the light of civilization, by maintaining the only camp of learning, whereas in Europe at this time the lamp remained unlit (Fig. 5).

The religious influence of the Koran has often been blamed for the absence of originality and progress in Arabic medicine; it has been said, for example, that the Koran forbade dissection (Fig. 6). This is only partially correct, however, because practical considerations of climate would be uppermost in extremely hot countries, where cadavers putrefy rapidly. Also the Greeks had already accomplished most of the anatomical studies of interest and, therefore, the Arabic student of medicine saw no need to duplicate earlier efforts.

The concept of a physician doubling as a surgeon was rarely acceptable in the Arabic tradition of medical practice. Instead, it was expected that the physician would confine himself to writing learnedly, speaking ex cathedra and assigning the menial tasks of surgery to an individual of lower class, the surgeon himself. As a result, the advances in surgery and anatomy that had been developed by the great Alexandrians, among others, were essentially ignored or lost (Fig. 6), whereas the writings of men such as Galen of Pergamon and Paul of Aegineta were merely translated into Arabic and codified. Despite these deficiencies, major Arabic physicians of this period (10th–12th centuries) thrived. Among the most illustrious scholars were Avicenna (980–1037), Rhazes (865–925), Avenzoar (died 1162), Albucasis (1013–1106), and Averroes (1126–1198). In the writings of these great physicians one finds an extraordinary effort to canonize the writings of their Greek and Roman predecessors. Thus Arabic scholars and physicians served as academics and guardians of what had become hippocratic and galenic dogma.

Arabic medicine did introduce a great medical tradition, that of bedside medical care and teaching (Fig. 7). From the point of view of the surgeon, the relative or complete lack of dissection and the practice of surgery (except by individuals of inferior status) inevitably reduced any preoccupation with surgical art. The only major contribution was the reintroduction of the Egyptian method of hot cau-

---

**Fig. 5.** Early anatomical scene from a manuscript based on Avicenna, which has been attributed to Serefeddin Sabuncuoğlu, ca. early 18th century. From the author’s personal collection.

**Fig. 6.** The anatomy of the skeleton is represented in this early manuscript leaf from a work attributed to Avicenna. The early understanding of anatomy was quite primitive among the European and Arabic cultures. An early Arabic anatomical manuscript from the author’s collection.
History of spine surgery

tery to control bleeding, but its use in lieu of the scalpel to create a surgical incision proved unfortunate (Fig. 8).

Rhazes (Abu Bakr Muhammad Ibn Zakariya al-Razl (865–925)

The writings of Rhazes demonstrates that he was a scholarly physician, learned in diagnosis, and exclusively loyal to the Hippocratic teachings.36 Although primarily a court physician and not a surgeon, he nevertheless left writings on surgical topics that continued to be influential through the 18th century. Rhazes was one of the first physicians to introduce the concept of “concussion” and to advocate surgery for penetrating injuries of the skull, even though patient outcomes were almost always fatal. He introduced the use of animal gut as a material for sutures, and also provided one of the earliest descriptions of spina bifida.

Avicenna (980–1037)

An influential physician and philosopher of Baghdad, Avicenna (known as the chief or “second doctor” [the title of “the first doctor” being attributed to Aristotle]) extended the original Greek influence with a force so persuasive and durable it still reaches us today. His works were translated into Latin and became a dominant presence in major European universities well into the 18th century (Fig. 9). His major work Canon medicinae was an encyclopedic effort based on the writings of Galen and Hippocrates, wherein Avicenna’s observations are mostly clinical, bearing primarily on materia medica (Fig. 10).7 The Greek word Canon (kòmwn) refers to a straight rod, a carpenter rule, or a standard of measurement. As such, Avicenna’s work became the rule, the codification or benchmark of galenic and Greek medicine. In his Canon medicinae a number of interesting neurological findings can to be found. His greatest contribution must be the detailed translation of Galen’s collected works, the Opera Omnia. Included within this work is one of the earliest and most famous illustrations of a series of spine stabilizations. Within the text are many of discussions of various spine injuries along with the prognoses. In less serious cases the use of stabilization and even distraction is advocated to reduce and align the spine. Despite his advanced thinking, Avicenna was often quite fatalistic in his prognosis of these type of injuries. Rarely did he argue for surgical interventions because of the often dismal outcomes.

Albucasis (Al-Zahrawi 936–1013)

In the Arabic tradition Albucasis was a great compiler as well as a serious scholar, whose writings (~ 30 volumes) mainly focused on surgery, dietetics, and materia medica. In his introduction to the Compendium, there is an interesting discussion of why Arabic scholars made so lit-
The final section of the *Compendium* consists of a lengthy summary of the surgical techniques practiced at that time. Albucasis' work, which featured unique illustrations of surgical instruments, was used extensively in the schools of Salerno and Montpellier and, hence, became an important influence during the medieval period. Many of the instruments featured were designed by Albucasis himself and in the *Compendium* he describes them together with the technical aspects of their use. His design of a “nonsinking” trephine is classic and provided the basis for the patterns of many later instruments; it involved the addition of a collar surrounding the trephine in a circular fashion to preventpling. Some of the instruments Albucasis described were modeled on those described by Paul of Aegina; the practical reputations of these tools were evidently enhanced by their inclusion in the *Compendium*.

Albucasis' treatise on surgery is an extraordinary work. It is a rational, comprehensive, and well-illustrated text designed to teach the surgeon the details of each treatment, including the types of wound dressings to be used. Albucasis recognized the diagnosis of spinal injury, particularly dislocation of the vertebrae, and in cases of total subluxation he appreciated that the prognosis was essentially terminal, with the patient showing involuntary activity (passing urine and stool) and flaccid limbs. Regarding lesser spinal injuries, some methods advocated by Albucasis for injury reduction were rather dangerous in design, depending on a combination of spars and winches. He held that bone fragments in the spinal canal should be removed.

Chapter nine: On setting the vertebrae of the back and neck

When a fracture occurs in the bones of the neck, which is rare, as mostly they suffer contusion, as do the spinal vertebrae—when it happens to anyone and you want to know where it will heal or not, then look and if you see both his hands relaxed and numb and dead and he has no power to move or stretch or close them, and when you punch them or prick them with a needle he does not notice it or feel any pain in them, you may know, as a general rule, that it will not mend, for he is doomed. But if he moves them both and feels in them the pinching and pricking, you may know that the spinal medulla is still intact and that under treatment the patient will recover.

If anything of this nature happens to the vertebrae of the back and you wish to know if he will recover or not, then pay attention to his feet. If you see them relaxed and in the situation we described in the case of the hands, and when he lies on this back he passes flatus and faeces involuntarily, and lying prone he passes water involuntarily and lying on his back he cannot pass water if he wishes, then you may know this case is hopeless, so do not concern yourself with his treatment. But if nothing of this kind occur then the case is easier.

The way to treat this latter kind of case is to try to reduce the swelling by applying over the injured vertebra oil of roses. . . If the injury is accompanied by fragmentation or a separation of part of the bone, you must cut down on it and remove the bone; then bring together the edges of the opening, by suture if it be wide; then treat with granulating ointments until it heals.

If the last bone of the coccyx, which is the sacrum of the tail, breaks, introduce the thumb of your left hand into his anus and reset the bone with other hand in whatever way is possible and affords the best setting . . . if you perceive a fragment in the fracture, cut down upon it, remove it, and dress the wound as before said, until it heals.

**MEDIEVAL MEDICINE, THE PERIOD OF MEDICAL SCHOLASTICISM**

With the demise of the Arabic schools and the transition to medieval scholasticism, a new concept developed in which philosophical and metaphysical explanations and dialectical interpretations became prominent in the medical schools. A leading school at this time was that of Salerno, where despite the barbarian invasions, physicians were trained, libraries maintained, and a medical school was permitted to flourish (Fig 11).

**Constantinus of Africa (1020–1087)**

An important leader and educator in this institution, and a product of medical scholasticism, was Constantinus Africanus—magister orientis et occidentis—an important figure in the school of Salerno (Magistri Salernitani), who introduced Arabic medicine to that region and hence to all Europe. Constantinus studied at Baghdad, where he came under the influence of the Arabists, and later retired to a monastery at Monte Cassino where he translated Arabic manuscripts into Latin, albeit rather inaccurately. Some historians considered him no more than an unscrupulous plagiarist and unreliable translator, but he did translate texts from Arabic to Latin (his writings mark the
Thus began a new translation of medical texts back again into Latin (continuing the legacy of Galen), with the Hippocratic writings remaining the inexhaustible source of medical and surgical information. Constantinus’ example allows one to gauge how much medical and surgical knowledge was lost or distorted by inaccuracies in the course of successive translations, particularly those of anatomical works. It is notable that Constantinus reintroduced anatomical dissection by performing an annual dissection of a pig, but, unfortunately, the anatomical observations that were made as the dissection progressed were compared with those recorded in classical Greek works, and any contemporary finding that did not match that of the ancient texts was simply ignored. Constantinus is representative of a period of extensive compilation in which an original thought or advance in knowledge was notable chiefly by its absence. From this period, however, came the Regimen sanitatis Salernitanum, a work that first appeared in the 12th century and later was reproduced in approximately 140 different editions. Despite a strong educational system and a devotion to health care, this remained a period in which surgical education and practice continued to slumber. A review of the surgical texts produced at this time basically show only a reiteration of the writings of Hippocrates, Galen, Paul of Aegina, and the other classical figures.

Roger of Salerno (ca. 1170)

Roger of Salerno was a surgical leader in the Salerno tradition, the first writer on surgery in Italy. His work, Practica chirurgiae, had a tremendous influence on the medieval period, offering several interesting surgical techniques (Figs. 12–14). Roger introduced an unusual technique of checking for a tear in the dura mater or a leakage of cerebrospinal fluid in a patient with a skull fracture: while the patient held his breath (Valsalva maneuver), the surgeon watched for a cerebrospinal fluid leak or air bubbles. A pioneer in the techniques of managing nerve injury, Roger argued for the reanastomosis of severed nerves and paid particular attention to the nerves’ alignment.

In a 12th century manuscript attributed to Roger of Salerno (only recently translated from the original and formerly owned by Harvey Cushing), there is an interesting review of Salernitan surgery, the so-called “Bamberg surgery.” There is an early description of the use of a soporific mixture used to induce relief of pain in a patient about to undergo surgery. This medication was composed of the bark of a mandragora, hyoscyamus, and levisticum seed, which were mixed together, ground, and then applied wet to the forehead of the patient. In the field of anatomy Roger offered little new, contenting himself with recapitulating earlier anatomical treatises, in particular, those of Albucasis and Paul of Aegineta. In the surgical treatment of spinal disorders and fractures, this author followed the guidelines of the early classicists by favoring stabilization in cases of spinal subluxation. An important early manuscript kept in the British Library (Sloane Manuscript No. 1977) contains illustrated examples of patients with spinal injuries.

In summary this was a period in European history characterized by the devastation of war, famine, pestilence,
and general malaise. Medical knowledge was carefully guarded by monastic recluses in inaccessible mountain retreats. Despite this state of affairs some surgeons evidently succeeded in mastering their art in the midst of intellectual darkness.

Theodoric of Cervia (Borgognoni) (1205–1298)
An unusually inventive medieval surgeon, Theodoric of Cervia (also known as Theodoric Borgognoni of Lucca) is remembered as a pioneer in the use of aseptic technique—not the “clean” aseptic method used today, but rather one based on the avoidance of “laudable pus.” Theodoric attempted to discover the ideal conditions for good wound healing and concluded that they consisted of control of bleeding, removal of contaminated or necrotic material, avoidance of dead space, and careful application of a wound dressing that had been bathed in wine.

Theodoric’s surgical work, written in 1267, provides one of the best views of contemporary medieval surgery. He argued for meticulous (almost halstedian) surgical techniques. The aspiring surgeon trained under competent masters and seems to have been well read in the field of surgery. To assist the patient in tolerating surgery, he developed his own “soporific sponge,” containing opium, mandragora, hemlock, and other less important ingredients, which was applied to the patient’s nostrils until the individual fell asleep.

An important change in the type of wounds managed by surgeons occurred midway through the 13th century with the introduction of gunpowder into Europe by the Franciscan Friar Roger Bacon, and its prompt use in military endeavors. By the second half of the 14th century, cannons were being manufactured in Ghent. Handguns first appeared in the middle of the 15th century, although they were quite massive and clumsy to use. (Many examples can still be seen in European museums.) In 1515 a Nuremberg inventor created a wheellock mechanism, which led to the development of the musket, a weapon that proved to be devastating in battle, thus producing of much material for the surgeon.

William of Saliceto (1210–1277)
The ablest Italian surgeon of the 13th century and a professor at the University of Bologna, William of Saliceto wrote Chirurgia, which was highly original and not based on previous writings. Although William rarely quoted his sources, the work shows the influence of Galen and Avicenna. Book IV of Chirurgia is particularly important because it contains the first section dealing with regional or surgical anatomy. A major advance promoted at the time by William was replacing the Arabic method of burning with cautery with the use of the surgical knife. William’s other great contribution was devising a series of techniques for nerve suture anastomosis. Unfortunately, his works on fractures and disorders of the spine basically reiterate earlier views that these lesions are rarely treatable and they reflect a very conservative attitude toward surgery of the spine.

Leonard of Bertapalia (1380?–1460)
Leonard of Bertapalia was a prominent figure in 15th century surgery. Originating from a small town near Padua, he established an extensive and lucrative practice in that area and in neighboring Venice. Among the earliest
proponents of the study of anatomy, Leonard offered a course of surgery in 1429 that included the dissection of an executed criminal. Leonard appears to have had a strong interest in injuries of the head, because he devoted one third of his book to surgery of the nervous system. He considered the brain and spine to be the most precious of organs, regarding them as the source of voluntary and involuntary functions. His insights into fractures were remarkable. He proposed that the physician always avoid materials that might cause pus; never use a compressive dressing that might drive bone into the brain or spine; and if a piece of bone is piercing, remove it. His philosophy closely resembles that of a much earlier surgeon, Paul of Aegina.

Leonard assembled a set of rules to guide the practice of a 15th century surgeon that still remain applicable five centuries later.

To be the perfect surgeon, you must always bear in mind these eight notions, and remembering them you will be preferred to others. The first task to become a good surgeon should be to use his eyes. . . . Second, you must accompany and observe the qualified physician, seeing him work before you yourself practice. . . . Third, you must command the most gentle touch in operating and treating lest you cause pain to the patient. . . . Fourth, you must insure that your instruments be sharp and unrusted whenever you cut anywhere. . . . Fifth, you must be courageous in operating and cutting but timid to cut in the vicinity of nerves, sinews and arteries, and, so as not to commit error, you should study anatomy, which is the mother of this art. . . . perform your surgery cleverly and never operate on human flesh as if you were working on wood or leather. . . . Sixth, you must be kind and sympathetic to the poor, for piety and humility greatly augment your reputation and the sick will respect you more. Eighth, you must never argue about fees with the sick, or indeed demand anything unless it be previously agreed upon, for avarice is the most ignoble of vices and should you be so inflicted, you will never achieve the reputation of a good doctor.

**Lanfranchi of Milan (died 1306)**

Lanfranchi of Milan, a pupil of William of Saliceto and often called the father of French surgery, carried forward his teacher’s use of the knife in place of the cautery. Although Italian by birth, Lanfranchi was driven from Italy because of political strife. After seeking refuge in France, he produced his *Cyrugia parva*, a work in which he perfected the use of the suture for repairs. An innovative surgeon, Lanfranchi developed a method of esophageal intubation for surgery, a technique not commonly practiced until the 20th century. As an educated surgeon he attempted to elevate the art and science of surgery above the mediocre level of the barber–surgeon. In a traditional medieval fashion his treatment of spine lesions and trauma mirrored earlier views of stabilization. A bad prognosis was clearly evident in a patient who was unable to move his legs, one who was incontinent, or one who could not control his bowels. There is no discussion of actual surgery on the spine and thus it is unclear whether he would have advocated this form of treatment.

**Henri de Mondeville (died 1317)**

Henri de Mondeville, who taught at Montpellier, was an important figure in the history of French medicine and surgery. He offered some new wound treatments (opting for cleanliness and avoiding “laudable pus”) and argued for healing by primary intention—an original concept for this period ("modus novus noster"). In the surgical treatment of wounds he argued for removal of foreign bodies and the use of wine dressings in wound care—the wine acting as an antiseptic and providing better healing. Henri began writing his treatise on surgery in 1306, but was unable to finish it because of poor health (tuberculosis). He was also a designer of surgical instruments and, in particular, is remembered for the creation of a special needle holder and also an instrument for extraction of arrowheads. The inclusion of illustrations in his *Chirurgie*, especially anatomical depictions, was of great importance to Henri. His work is considered the first to actually make use of illustrations for teaching purposes, a concept unheard of in the 14th century, but widely accepted since the Renaissance.

**Guy de Chauliac (1300–1368)**

The most influential surgeon of the 14th and 15th centuries and a writer who demonstrated rare learning and a fine historical sense, Guy de Chauliac exerted an influence so great that he became physician to three popes at Avignon (Clement VI, Innocent VI, and Urban V) and a leading surgeon at the school of Montpellier. His work was copied and translated well into the 17th century and was considered to be the principal didactic surgical text (*Collectorium cyrurgie*, AD 1363) of this period (Fig. 15). Guy posited four conditions that must be satisfied for a practitioner to be a good surgeon: 1) the surgeon should be learned; 2) he should be expert; 3) he must be ingenious; and 4) he should be able to adapt himself (from the introduction of *Ars Chirurgica*). Guy advocated repair by primary suture and claimed good results. He used egg albumin to stop bleeding and provide adequate hemostasis, which always posed a difficult problem for surgeons. A major error on his part was to reintroduce the concept of laudable pus to the healing of wounds, which set back surgery approximately 600 years, until the time of Lord Lister in the latter half of the 19th century. Guy’s chief work on surgery was divided into three parts, the second of which deals with a number of subjects, most particularly with wounds, fractures, and dislocations. A combination of accurate anatomical explanations, careful surgical diagnoses, and superb medical ethics pushed this surgeon to the forefront. In addition to his surgical skills Guy advocated patient comfort and for this he used a narcotic sponge for anesthesia. He was not fearful about cutting out superficial tumors, yet was cautious in cutting for the stone. He treated fractures and dislocations with splinting and suspension, often using a weight-pulley system similar to that advocated by Avicenna. The writings of Guy de Chauliac remained influential in Europe until the publications of Ambrose Pare in the 16th century. The first printed edition of Guy’s work appeared in 1478; it was followed by approximately 70 editions over the next several centuries, proving to be a most influential work.

Guy de Chauliac had this to say about the treatment of wounds:

1. To remove foreign bodies, if there be any between the divided parts.

CONCLUSIONS

The Arabic and medieval era were periods of great intellectual activity, but also of somnolence as far as originality of thought is concerned. Faith in the teachings of antiquity was excessive. From the fall of the Roman Empire until the beginning of the 16th century, anatomy and the practice of surgery, with only rare exceptions, lay dormant, chained to a staunch galenic orthodoxy. The translation of writings from Latin, Greek, and Hebrew into Arabic and back into Latin resulted in many errors of interpretation. Lack of true anatomical knowledge and poor surgical outcomes naturally led physicians to recommend against operating on spine and the spinal cord. A review of early treatises shows that, despite intellectual paralysis, there still existed a number of prominent personalities who did make some advances. It was not until the 19th century, however, with the introduction of cerebral localization, antisepsis, and anesthesia, that the "modern" development of neurosurgery flourished.

The history of medicine consists of a successive series of intellectual movements proceeding from different centers and each engulfing its predecessor.41

References

10. Celsus AC: De Medicina, Florence: Nicolaus Laurentii, 1478
History of spine surgery


34. Paulus of Aegineta: Opus de re medica nunc primum integrum. Coloniae: Opera et impensa Ioannis Soteris, 1534


36. Rhazes ABM: Opera parva. Lyon: Impressa per Gilbertum de Villiers, impressis Johannis de Ferris, 1511

37. Riesman D: The Story of Medicine in the Middle Ages. New York: PB Hoeber, 1936, p 211


Manuscript received November 3, 2003. Accepted in final form December 11, 2003. Address reprint requests to: James Tait Goodrich, M.D., Ph.D., Leo Davidoff Department of Neurological Surgery, Albert Einstein College of Medicine, Children’s Hospital of Montefiore, 111 East 210th Street, Bronx, New York 10467. email: goodrich@ aecom.yu.edu.