SPINAL COLUMN INJURIES: FROM THE VERY BEGINNING

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The history of medicine is interesting and instructive. In each of the many branches of medical science, the specificity of pathology determines diagnosis and treatment. These processes inevitably continue in time and space in accordance with the conditions existing in a given place and in a given period of time. Spine injury is one of the most striking examples of the longevity and duration of this process. Humanity relatively recently discovered what diabetes is and how it should be treated, but this branch of medicine also has its own history, although not a very long one. Spinal injuries have accompanied man and his predecessors almost always, disrupting the usual rhythm of life, and therefore they have been required to be treated since time immemorial. A true professional is always interested in the history of his specialty. Spine surgeons are no exception. What we managed to collect bit by bit, of course, is not everything, but it is impossible to grasp the immense, and it is necessary to know the past in order to better understand the present and the future.

Key Words: spine, injuries, vertebrology, spine surgery, history of medicine.

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The spine is something very special. Present-day science has a theory that vertebrates (Diplodocus carnegii) appeared on Earth approximately 525 million years ago, and since then there apparently were no fundamental changes in the anatomy and physiology of the spinal column. The human spine differs only in size and several anatomical aspects; it has just slightly changed over millions of years. We do not know how our distant ancestors, that is, Neanderthals, Denisovans, Sapiens, etc., treated spinal injuries, however, we may suggest that such injuries were inescapable based on the information on their mode of life (hunting large animals, climatic cataclysms, etc.). There is no available evidence of their medical activities. Only ancient times gave us the legacy represented by not only writing and works of art, but also by the evidence of human wisdom and expertise, including the field of medicine.

The Ancient World is broadly defined as the region of the Mediterranean and India. In Sanskrit, the spine (referred to as "Merudanda") is the axis of the Universe. Other ancient cultures also have many references to the spinal column. There is reason to suppose that the history of the spine began in India. As for injuries, the ancient surgeon Susruta gave the detailed description of a method for treating cervical vertebral injuries. For dislocations, he recommended grasping the head and traction along the length of the cervical spine.

The development of spinal surgery can hardly be called true before the 20th century. In ancient times, physicians were often afraid to perform surgical interventions. Hammurabi, the king of Babylon (1955–1912 BC), issued a set of laws covering all the most important areas of life. The punishments for surgeons mentioned in it allow suggesting that they treated their patients anxiously. There were 9 paragraphs on medical issues; one of which interpreted the actions of a physician with a bronze knife as follows: "If a physician makes an incision and the patient is a free man, he receives 10 silver coins; if the patient is the son of a man of lower class, the physician receives only 5 coins; and only 2, if the patient is a slave. If a physician treats a patient for a serious injury with a metal operating knife, and this leads to a patient's death, physician's hands shall be cut off." Breakthrough technologies can be hardly developed under such conditions.

Four stages can be distinguished in the history of the development of ancient and medieval medicine: Egyptian-Babylonian (primitive), Greek and Roman (the beginning of spinal surgery), Arabic (pre-scholastic), and Medieval (scholastic).

Egyptian and Babylonian Medicine

The history of ancient Egypt includes 30 dynasties of the Old, Middle and New Kingdoms. The oldest example of medical literature from this vast (over 3,000 years) period of time is the so-called Edwin Smith Papyrus (or Surgical Papyrus) that was written after 1700 BC, that is, during the New Kingdom period. It is the oldest known surgical writing. The papyrus is 15 feet long and 1 foot wide, and is probably an incomplete copy of a text dated 2686–2181 BC.

It is based on material accumulated over a thousand years. This document contains 22 pages and describes 48 injuries of different locations; each description includes physical examination, treatment, and prognosis. The papyrus is named after the American archaeologist Edwin Smith who bought it for his collection in Luxor in 1862 either from a dealer named Mustafa Agha or from tomb robbers. Edwin Smith was a strange and controversial figure; he was considered an adventurer, a profiteer, a forger of antiquities, a pioneer in the research of Egyptian artifacts, a man of "tremendous talent." Smith realized the value of this document; however, he did not publish it. When Smith died in 1906, the papyrus was carried over to his daughter, and she presented it to the New York Historical Society. The Society asked James Henry Breasted to translate it, and this task

was completed by him in 1930. In 1938, the papyrus was sent to the Brooklyn Museum and was first exhibited in 1948 at the Metropolitan Museum of Art in New York. In the same year, it was presented to the New York Academy of Medicine, where it remains today (Fig. 1).

Unfortunately, the manuscript was not finished; it breaks off in the middle of a sentence. The beginning and end of the original text are lost; the author's name was not mentioned. The author of this text might be Imhotep, a great ancient Egyptian architect and scientist, who is considered to be the father of Egyptian medicine. We don't know whether it is true or not, perhaps we just do not know the names of other great ancient Egyptian scientists.

The surgical procedures described in the papyrus seem to be quite reasonable, although there are also magical spells to fight against plague. The text starts with the treatment for head injuries followed by the treatment for injuries to the neck, arms and torso, and then the text breaks off. The following procedures are described: closing wounds with sutures (for wounds of the lip, throat and shoulder), preventing and treating infection with honey, and stopping bleeding with raw meat. The use of magic was mentioned in only one case (case 9).

The papyrus also describes anatomical observations. It contains the first known description of the cranial sutures, the meninges, the outer surface of the brain, the cerebrospinal fluid, and the intracranial pulsations. However, the physiological functions of organs and vessels remained an object of mystery to the ancient Egyptians. Injuries to the cervical and thoracic spine are provided in six cases.

Case 29: Instructions concerning a gaping wound in a vertebra of (his) neck.

If you examine a man who has a wound in a vertebra of his neck penetrating to the bone and perforating a vertebra of his neck, and if you examine that wound, and the patient shudders exceedingly, and he is unable to look at his two shoulders and his breast, you should 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". You should 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 30: Instructions concerning a sprain in a vertebra of (his) neck

If you examine a man having a sprain in a vertebra of his neck, you should say to him: "Look at your two shoulders and your breast." When he does so, the seeing possible to him is very painful. You should say concerning him: "One having a sprain in a vertebra of his neck. An ailment which I will treat". You should bind it with fresh meat the first day. Now afterward you should treat with ymrw (apparently a mineral substance with disinfectant properties) and honey every day until he recovers. As for "a sprain", the physician is speaking of the separation of two vertebrae, with each of them is in its usual position.

Case 31: Instructions concerning a dislocation in a vertebra of (his) neck.

If you examine a man having a dislocation in a vertebra of his neck, you will 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 flows out in drops without his knowing it; the patient has shortness of breath, his two eyes are blood-shot. It is a dislocation of a vertebra of his neck extending to his spine 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. You should 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". As for "a dislocation in a vertebra of his neck", the physician is speaking of a separation of one vertebra of his neck from another, the flesh which is over it being uninjured. As one says, "It is a dislocation", it means things which had been joined together, when one has been severed from another. As for, "it is an emissio seminis which befalls his phallus", it means that his phallus is erected and has a discharge from the end of his phallus. It is said "it remains stationary" when it cannot sink downward and it cannot lift upward. As for, "while his urine dribbles", it means that urine drops from his phallus and cannot hold back for him.

Case 32: Instructions concerning a displacement in a vertebra of his neck

If you examine a man having a displacement in a vertebra of his neck, whose face is fixed, whose neck cannot turn for him, you should say to him: "Look at your breast and your shoulders," and he is unable to turn his face that he may look at his breast and this two shoulders. You should say concerning him: "One having a displacement in a vertebra of his neck. An ailment which I will treat". You should bind it with fresh meat the first day. You should loose his bandages and apply grease to his head as far as his neck. You should treat it afterward with ymrw

Fig. 1
Smith Papyrus (photo from open sources)

and honey every day, and his relief is sitting until he recovers. As for "a displacement in a vertebra of his neck," a physician is speaking concerning a sinking of a vertebra of his neck to the interior of his neck, as a foot settles into cultivated ground. It is a penetration downward.

Case 33: Instructions concerning a crushed vertebra in his neck

If you examine a man having a crushed vertebra in his neck and you find 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 if you find he is unconscious of his two arms and his two legs because of it, you should 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". As for "a crushed vertebra in his neck", a physician is speaking of the fact that one vertebra of his neck has fallen into the next, one penetrating into the other. As for "his falling head downward has caused that one vertebra crush into the next", it means that he has fallen head downward upon his head, driving one vertebra of his neck into the next.

Case 48: Instructions concerning a sprain of a vertebra in his spinal column

If you examine a man having a sprain in a vertebra of his spinal column, you should say to him: "Extend now your 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. You should say concerning him: "One having a sprain in a vertebra of his spinal column. An ailment which I will treat". You should place him prostrate on his back; you should make for him... (there is the end of notes related to the surgical treatise).

Greek and Roman Period

The evolution of spinal surgery began in the Golden Age of Greece, with the founding of the Alexandrian school. The implementation of cadaver dissection into the curriculum was a huge advance, although the material for physicians' training was provided by continuous wars. Among many similar episodes of the Iliad, Homer describes how Achilles strikes his enemy with a sword on the neck, the head with helmet comes off of his body, the spinal cord becomes visible, and the body hits the ground.

The author of the earliest texts of this period was Hippocrates of Cos (460–370 BC; Fig. 2). These texts demonstrated that actual surgical interventions on the spine were very rare. The injured spine was commonly immobilized with external splints. Hippocrates writes: "...the spinal cord suffers damage when a vertebra is displaced, even at slight curvature, since the displaced vertebra compresses the spinal cord. Even if the spinal cord is intact, its compression and tension lead to the impaired sensitivity of its important parts... under these conditions, it is clear that this cannot be eliminated by suspension or any method other than making an incision and introducing the hand into a large cavity and exerting pressure from the inside out, however, this can be done on a dead body, not on a living one. Why do I write this? Inasmuch as several people pretend that they can treat patients with a vertebra that is dislocated and completely displaced forward. Someone believes that these are the easiest cases of reposition, since they require no treatment, and the reposition occurs spontaneously". This text demonstrates that Hippocrates was not committed to perform surgical interventions (Fig. 3). External stabilization and immobilization were the method of choice. The reasons included poor outcomes, the risk of suppuration, and minimal anesthesia.

Herophilus of Chalcedon (300 BC) was a student of Praxagoras and Chrysippus. He performed more than 100 dissections of cadavers, and took part in the challenge of developing an anatomical nomenclature and the extremely required language of anatomy. Investigating the nervous system, Herophilus established that nerve trunks originated from the spinal cord and subdivided them into sensory and motor types. Moreover, he corrected the old common mistake by differentiating between nerve trunks and tendons. He had a good understanding of the severity of complicated spinal injuries and believed that surgical treatment should be avoided in such cases.

Aulus Cornelius Celsus (25 BC–50 AD) was neither a physician nor a surgeon; however, he was an encyclopaedist. His works provide an analysis of the three leading medical schools of his time: dogmatic, methodical, and empirical. As a consultant to two emperors, Tiberius and Caligula, he obtained fame and respect. His major work, De Medicina, was lost, then re-discovered in 1443, and published in 1478, whereafter it became known to the medical community. In this work, he writes, in particular, that injuries to the cervical spine cause nausea and vomiting, as well as breathing disorders. Trauma to the lumbar vertebrae results in paralysis of the legs and dysfunction of the pelvic organs. Just like Hippocrates, Celsus did not recommend surgical interventions for spinal injuries.

Galen of Pergamon (129–200 BC) was a follower of the ideas of Hippocrates and the Alexandrian school (Fig. 4). He wrote works from the age of 13 until his death. Even if we exclude his works on the Corpus Hippocraticum, his written legacy makes up to 80 % of all antique medical treatises. The present-day edition of his papers is presented in 22 books. He lived in the time of the emperors Antoninus Pius and Marcus Aurelius. As a physician who treated gladiators, he had profound experience in treating battle injuries. His anatomical experiments on transection of the spinal cord helped to determine the nature of disorders depending on the transection level. He identified the cranial nerves and was able to demonstrate 11 out of 12. He rejected the idea of the glandular nature of the spinal cord made by Hippocrates, and supposed that active movements and sensitivity were its functions. These considerations were without doubt a conceptual progress of medical science. It was he that invented the terms "kyphosis", "lordosis", and "scoliosis". He was the first to describe the condition that is now known as Brown-Sequard syndrome, i.e. hemiplegia with loss of sensation on the opposite side because of the hemisection of the spinal cord. His surgical experience allowed him to become much

more progressive in regard to surgical interventions for injuries, in particular, for the spinal injuries, than his predecessors and contemporaries. For example, he recommended decompression surgeries for injuries of the brain and spinal cord. After Galen's death, his legacy turned into a vast set of dogmas, and he was actually canonized by Arab and medieval physicians. This continued until the Renaissance.

Paul of Aegina (625–690 AD) was the last physician of the Byzantine Empire who was well-known for his fundamental work that included accumulated knowledge and experience of his ancient predecessors regarding the treatment of patients with diseases and injuries of the spinal column (Fig. 5). This is about the 7-book anthology "Epitomoe Medicae Libri Septem". Like other Byzantine physicians, Paul of Aegina, a student of the Alexandrian school, based his ideas on the works of Hippocrates, Aristotle, Herophilus, Celsus, and Galen (Fig. 6). His studies greatly influenced the Islamic and Renaissance European medicine and played a valuable role in medical practice until the 17th century. The anthology was translated into Latin by Johann Winter in 1532. Information on the treatment for spinal injuries is included in volume 6.

Paul was born on the island of Aegina, a prosperous colony of the city of Epidaurus. There are few known facts about his life. He traveled a lot, studied Islamic medicine that was perhaps the most advanced of the post-classical period. In the late Byzantine period, he went to Alexandria and continued his work despite the Turkish invasion. His experience and knowledge earned him a reputation as the last of the great Byzantine physicians.

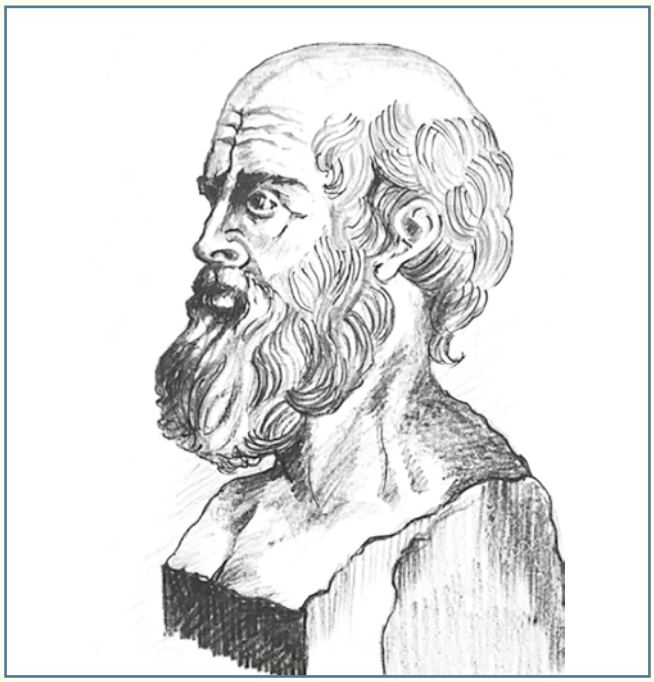


Fig. 2
Hippocrates [10]

Section 98 of volume 6 of his anthology describes traumatic vertebral fractures. He starts with the description of burst fractures and high mortality rate because of cervical spine injuries. "Round vertebral bodies may sometimes be crushed... in such cases the spinal cord meninges... are compressed due to the sympathetic nerves, and death follows quickly especially with a fracture of cervical vertebra". In such cases, Paul recommended surgical removal of the compressing bone fragment. This may be considered as the first description of laminectomy for complicated spinal injury. He describes fractures of the spinous processes that are "easily identified by palpation". He recommended to replace the fragment of the process or to make an incision and to remove it. The same method is used for sacral fractures. Closed reposition using digital rectal examination was recommended. If a bone fragment is palpated, it should be removed by surgical intervention.

Fig. 3
Hippocratic apparatus for repositioning a displaced vertebra [9]

Section 117 describes the treatment for vertebral dislocations, and its contents were in full adopted from the texts of Hippocrates. Paul highlights the high mortality rate associated with such injuries: "complete dislocation causes sudden death, since the spinal cord is exposed to extremely strong compression". Exogenous impact can cause instability and result in one of three types of subluxation: spondylolisthesis, retrolisthesis, or laterolisthesis. Complete dislocation causes spinal flexion (kyphosis) that is more dangerous than partial one with the involvement of several vertebrae (circular flexion). Paul argued against classical methods of reposition for dislocations. He supposed that fastening to a ladder and shaking in mid-air (succussio) was ineffective. He disagreed with the earlier idea of the common misdiagnosing of minor vertebral fractures with anterior dislocation. Since such fractures heal with callus formation, anterior dislocations are considered minor injuries: "...these injuries are actually incurable or rarely curable, since dysfunction of the pelvic organs develops along with body cooling". As for retrolisthesis, Paul distinguished traumatic and congenital deformities; the latter "...lead to diseases and are incurable".

Paul's works were regarded as a reliable guidance from the 7th to the 12th century. He was considered the last representative of Greek medicine. This reputation is the result of his compilations of Greek texts – an honorable tradition that ended off with his death. As mentioned earlier, the works of Paul of Aegina demonstrated significant influence of Islamic physicians, including Rhazes, Haly Abbas, Avicenna, Albucasis, and the Italian Girolamo Fabrici d'Acquapendente. Albucasis analyzed the neurological signs of vertebral fractures at different levels. He found that cervical injuries lead to "paralysis and loss of sensation in the arms" and that treating such patients makes no sense due to the lack of chances. Acute injuries to the thoracic spine require emergency care, especially in cases of impaired sensation in the legs and pelvic organ dysfunction such as incontinence. Like Paul of Aegina, he recommended the removal of compressing bone fragments.

In turn, Paul's works had an effect on Avicenna whose famous Canon of Medicine was translated into Latin by Gerard of Cremona in the 13th century.

With great skill, Paul of Aegina developed a whole range of instruments (Fig. 7, 8) for practical surgery. During interventions, he used woolen balls dipped in rose oil and wine for an antiseptic effect, and compression bandages for hemostasis. His principles of tissue restoration and wound suturing became an important milestone in surgery development.

Arab Period

After the Greek and Roman period, intellectual centers, including medical ones, moved to the Arab countries and Byzantium; they were dominating from about 750 to 1200. Intellectual ideas in Europe were suppressed by "barbarian" invasions (Huns, Goths, Vikings, etc.). In surgery, including spine surgery, this time was a "hibernating" period. Arabic scientific schools with extraordinary enthusiasm brought back the works of Greek and Roman scientists; all available works were translated and studied by the end of the 9th century. Unfortunately, one of the typical features of the Arabic schools was rigid dogmatism

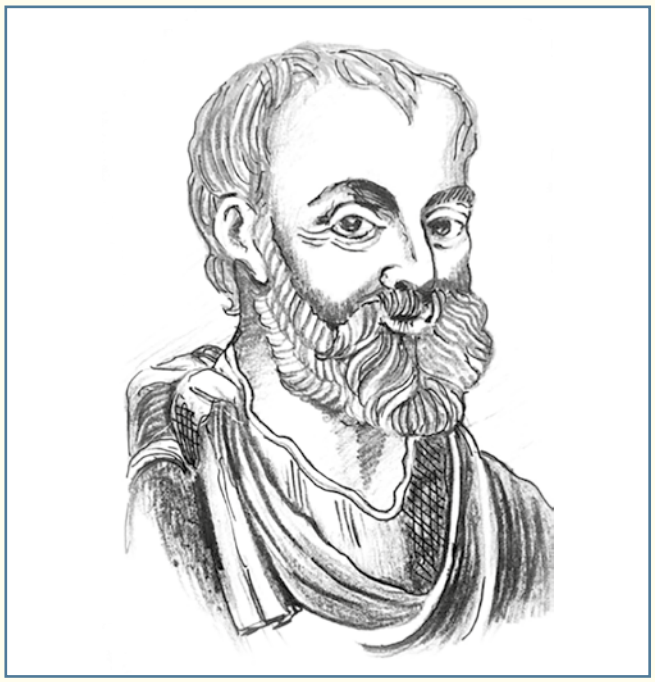
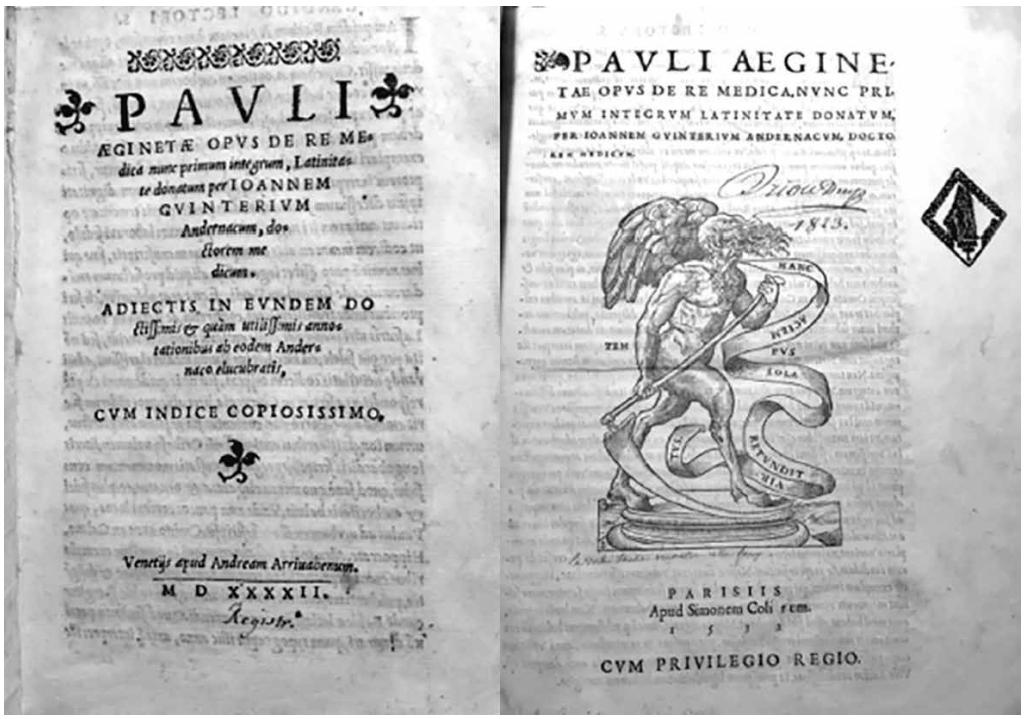


Fig. 4
Galen [10]

Fig. 5
Paul of Aegina [10]


PAVLI
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TAE OPVS DE RE MEDICA, NVNC PRI
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PER IOANNEM GVINTERIVM ANDERNACVM, DOCTO
REM MEDICVM.
1543.
PARISIIS
Apud Simonem Colinæum.
CVM PRIVILEGIO REGIO.

Fig. 6
First page of the eighth Latin edition of the Epitome by Paul of Aegina, Venice, 1542 [9]

that did not allow going a step further than translation and systematization. However, we should mention that the Arabs managed to maintain their love for knowledge while Europe was in the period of darkness.

The idea of "one person as a physician and a surgeon" was not accepted in Arab medical practice. A physician was expected to write papers and speak from the pulpit, and the "low" surgical tasks were intended for the "lower" class. Therefore, Greek and Roman achievements in surgery and anatomy were often disregarded; at its best, they were only translated into Arabic. Otherwise, Arab physician tried to canonize the works of Greek and Roman specialists. The almost complete cancellation of surgical practice resulted in a corresponding attitude towards the surgical art as a whole. Only the Egyptian method of stopping bleeding by cauterization was left. However, there were Arabic philosophers who were interested in the issues of spinal injuries and their treatment.

Rhazes (Abu Bakr Muhammad Ibn Zakariya al-Razi, 865–925) knew and respected the works of Hippocrates perfectly well. Although not a surgeon, he left a number of works that had an impact on specialists until the 13th century. He introduced the idea of "concussion", recommended surgical treatment for penetrating head injuries; it was he who gave one of the first descriptions of *spina bifida*.

Abu Ali al- usayn bin Abdullah ibn al- asan bin Ali bin Sina al-Balkhi al-Bukhari (in Europe – Avicenna; 980–1037), a physician and philosopher from Baghdad, was known as the "second physician" (the "first physician" was Aristotle). His works were translated into Latin and studied in all European universities until the 18th century. His major work was the Canon of Medicine, an encyclopedia based on the works of Galen and Hippocrates (Fig. 9). He translated Galen's Opera Omnia in detail. This work includes a series of figures on the subject of spinal stabilization. In mild cases, reduction and immobilization were recommended (Fig. 10). Avicenna was very pessimistic about the prognosis for spinal injuries; he considered surgical intervention to be very rarely indicated in such cases. In the fourth book of the Canon, Avicenna emphasizes the relationship between vertebral body dislocation and spinal cord injury. Like Paul, he recommended careful removal of all bone fragments compressing the spinal cord. There is, however, no evidence that European surgeons followed these recommendations until the 15th century (Fig. 11).

Albucasis (Al-Zahrawi, 936–1013) is considered a great compiler in the Arabic tradition; his legacy is up to 30 books. In the preamble, he emphasized that the insignificant progress of Arabic medicine in the field of surgery was because of poor knowledge of anatomy and classic papers. He gave the detailed description of the clinical presentation of complicated and uncomplicated cervical dislocations (he considers them to be rare in comparison to contusions) including the range of motion and abnormal sensation in the arms, and concluded

about the chances for recovery in each specific case. For thoracic spinal injury, particular attention should be paid to the patient's legs, bowel and bladder function; a treatment prognosis should be made based on the data obtained. The treatment included an attempt to reduce the "swelling" and making an application with rose oil. If the injury is accompanied by "...fragmentation and dislocation of bone fragments," surgery and bone restoration are required followed by wound suturing".

Medieval Medicine of Europe: Scholasticism*

The works of Arab scientists reached Europe in the 11th–12th centuries, that is, during the height of scholastic medicine. Their influence in medieval Europe decreased under the strength of the metaphysical interpretation of medical knowledge. This was a period of rewriting classical texts with minimal development of surgery. History should be taken as is: European surgeons of those years often had little education and were not able to contribute to the development of surgery. This period of "stagnation" is represented in the works of many European scientists. Roger Frugard, Roland of Parma, Lanfranc of Milan, Henri de Mondeville and other physicians had very conservative ideas on the treatment for spinal injuries. No one but William of Saliceto recommended the removal of bone fragments – but only in cases of open fractures. Spinal fractures, especially complicated ones, were considered inoperable and fatal.

Surgeries on the spinal cord and brain were recommenced in the 15th century by Leonard of Bertipaglia. Surgical interventions that he performed were adventurous for that time. For spinal fractures, he recommended removing any bone fragments compressing the spinal cord, while using only the cleanest materials to prevent suppuration. In the 16th century, Ambroise Paré developed these ideas in his classic work, Dix Livres de la Chirurgie; he proposed manual reposition and splinting of spinal dislocations to decompress the spinal cord. All this was described by Paul of Aegina 1,000 years before; this fact indicates high innovation in the works of the great Greek physician.

* *Scholasticism is a medieval philosophy with a developed system of artificial and purely formal logical arguments for the theoretical justification of church dogmas; knowledge that is away from reality of life and is based on abstract opinion that cannot be verified by experience; punctiliousness.*

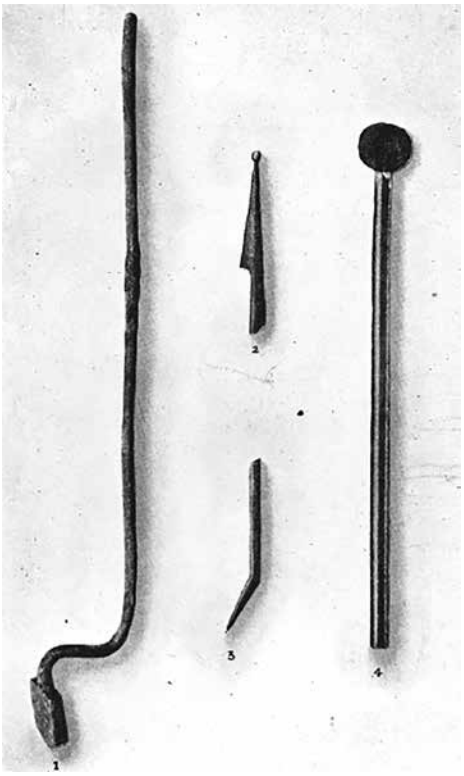

Fig. 7
Meningophylax – a plate inserted under the bone being removed to protect the underlying tissues [9]

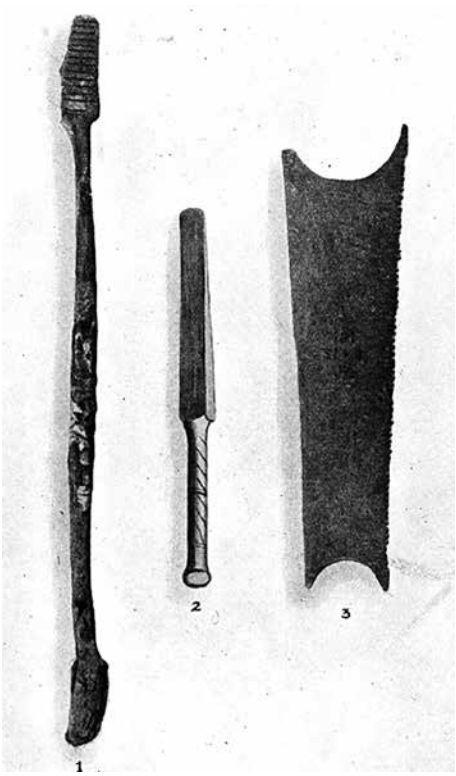

Fig. 8
Forceps of Greek and Roman surgeons. The medium ones were used by Paul of Aegina to remove bone fragments [9]

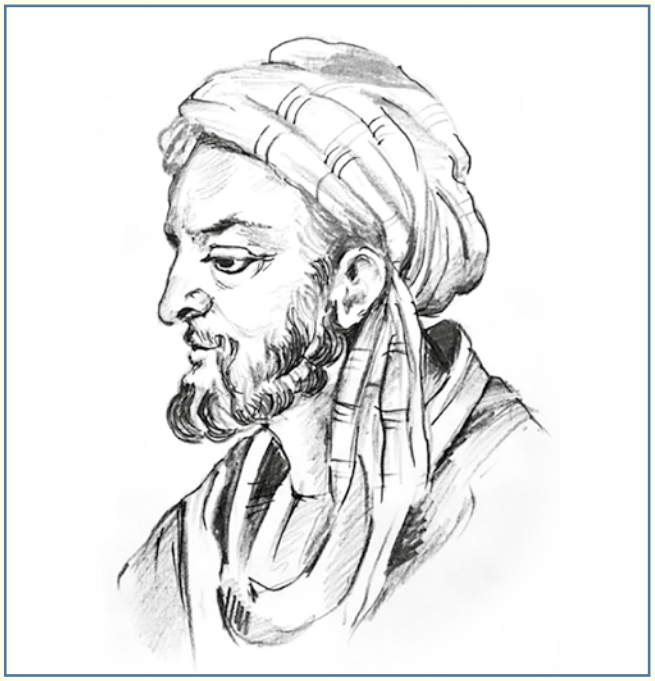

Fig. 9
Avicenna [10]

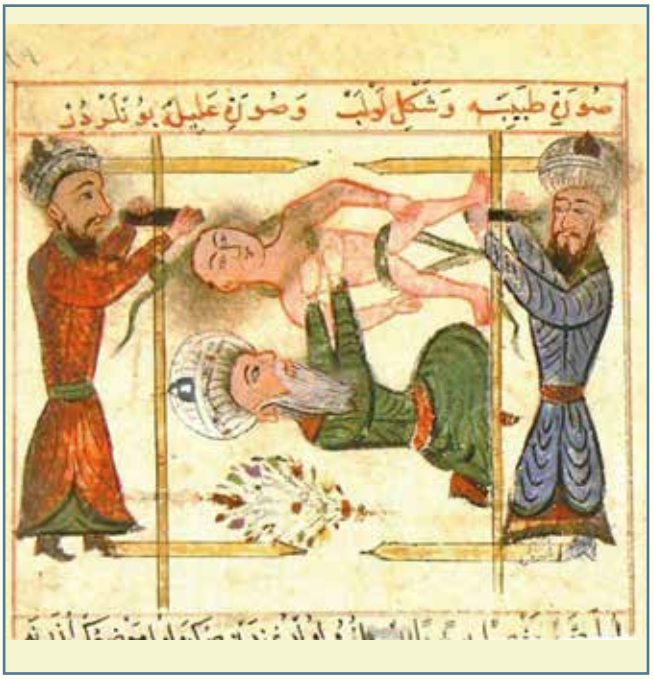

Fig. 10
Repositioning of a displaced vertebra [8]

After the fall of the Roman Empire, there was a 1,000-year period of stagnation in the European medicine. Several clerics tried to maintain the traditions of Greek and Roman medicine. However, in the 12th century, the church forbade clerics from practicing medicine when the Council of Tours (1169) decreed "Ecclesia abhorret a sanguine" meaning that bleeding was incompatible with serving the Lord. The decree limited the methodical teaching of surgery and actually leaved this art in the hands of poorly educated barber surgeons.

Among other things, the period of medieval scholasticism is characterized by a new concept that implemented philosophical and metaphysical interpretations of known processes and phenomena and their dialectical interpretation to the medicine. Only in the 13th century, a scientific school was organized in Salerno that was based on the traditions of Greek, Roman, Arabic, Jewish, and Asian medicine. It was equipped with experienced physicians, libraries, and love for knowledge (Fig. 12).

Constantine the African (1020–1087) was the head of the school of Salerno; he contributed to the introduction of Arabic medicine into the European world. He studied in Baghdad, and later was the monk of Monte Cassino monastery where he translated, although very inaccurately, Arabic manuscripts into Latin. Someone considered him to be a plagiarizer and an unreliable translator; however, his works contributed to the improvement of European medicine with the works of not only Arab but also Greek and Roman authors. Constantine conducted anatomical studies on pigs, although when comparing his findings with the descriptions of the classical authors, he completely ignored the facts that did not coincide with the findings of the great

Fig. 11
Tomb of Avicenna in Isfahan, Iran (photo from open sources)

Greek and Roman scientists. In general, the new period in the development of European medicine can hardly be characterized otherwise than rewriting and reviewing the works of the classical authors.

Roger of Salerno (1170) was also one of the leaders of the school of Salerno; his work "Practica chirurgiae" had a great influence on the development of surgery during this period (Fig. 13). He proposed a method for diagnosing tears of *dura mater* and liquorrhea in open cranial vault fractures: when a patient holds the breath (Valsalva test), a surgeon observes flowing cerebrospinal fluid or air bubbles. He described a soporific mixture that contained mandrake root, levisticum seed, *hyoscyamus*, and soil. It should be applied to the patient's forehead. As for spinal injuries, Roger shared the views and practices of the early classical authors. It was a challenging time for Europe, with wars, famine, and plague. Medical knowledge was maintained by hermit monks in mountain monasteries. However, even in these conditions, there were surgeons who continued to improve their skills.

Theodoric of Cervia (1205–1298) demonstrated no significant achievements in the field of spine medicine; however, he became a pioneer of surgical aseptic technique. He tried to find the perfect conditions for aseptic wound healing, and came up with opinion that these included bleeding control, removing contaminated and necrotic tissue, eliminating empty spaces, and carefully covering the wound with a dressing soaked in wine. He was criticized for considering pus to be a harmful component of the wound healing process, since it was commonly believed that pus was a sign of normal wound healing (*laudable pus*). He developed a soporific sponge containing opium, mandrake, hemlock, and other ingredients that was applied to the patient's nostrils and held until he fell asleep. He wrote "Chirurgia de Theodoric" where he identified in the group of patients with cervical spine injuries those who "should be treated" and those who should be "left alone". Diagnosis was based on neurological examination and external signs of spinal column deformity, kyphotic or lordotic. Treatment technically had little difference vs the present-day one: correction by axial traction and external immobilization (Fig. 14). Patients with complicated fractures of the thoracolumbar spine had poor prognosis. Kyphotic deformities were considered potential in regard to the possibility of external corrective measures, and lordotic ones were not, since manual or instrumental correction was impossible.

It would be unjust to our medieval European colleagues not to mention the new things that they managed to do. Thus, in 1646, Fabricius von Hilden, a German scientist, tried to perform reposition of a cervical dislocated fracture using a silver wire inserted with a needle transcutaneously and through the interspinous ligaments around the spinous process. By pulling on this wire, von Hilden tried to place the displaced vertebra to its normal position (Fig. 15). This was apparently the first vertebral metal implant in history.

William of Saliceto (1210–1277) was one of the most talented surgeons of his time. His "Chirurgia" was an original work with much new information for that period. He paid much attention to the knowledge of surgical anatomy, replaced the Arabic method of hemostasis by vessel cauterization with surgical manipulation, and developed a technique for nerve anastomosis. Unfortunately, his opinion on the treatment for spinal column injuries contained no fundamentally new ideas. Other well-known and even famous European surgeons of the Middle Ages did not deviate from the principles of the classical authors used in the treatment for spinal injuries and did not recommend surgeries to manage vertebral fractures and dislocations. We are talking about Leonard of Bertipaglia (1380?–1460), Lanfranc of Milan (died in 1306), Henri de Mondeville (died in 1317), Guy de Chauliac (1300–1368). All of them developed surgical technique. Thus, Lanfranc of Milan proposed the method of esophageal intubation for surgical interventions. This method became fairly widespread only in the 20th century. Henri de Mondeville invented the original needle holder, and Guy de


DE CONSERVANDA
BONA VALETVDINE,
Liber Scholæ Salernitanæ.

DE ANIMI PATHEMATIS, ET
remedijs quibuſdam generalibus.
CAPVT I.

ANglorum Regi ſcribit ſchola tota Salerni.
Sis tu incolumem, ſi vis te reddere ſanum,
Cura ſtolle graues, iraſci crede profanum.

B

Fig. 12
School in Salerno: Constantine the African gives a lecture [8]

Chauliac used egg white for hemostasis. Nevertheless, the technique of treatment for spinal column injuries underwent no progressive changes.

From the end of the 18th to the beginning of the 20th century

Dividing time into periods is an unrewarding job; everything is too complicated, both always and everywhere. However, in the history of spine surgery, one can distinguish a period of the 18th–20th centuries. It was during these years that scholasticism finally disappeared, materialism had a strong hold of minds, and the development of diagnostic and treatment methods (in the broadest sense) improved at an unprecedented pace.

Although John Bell (1763–1820), one of the American surgeons, stated in 1799 that "the cutting into the vertebra is a dream," the first laminectomy, according to W. Schmieden, was performed by A. Louis in 1762. Henry Cline performed a "trephination of the spine" in 1814. He removed a broken spinous process in the case of a dislocated fracture of the thoracic spine complicated with paraplegia. The patient died shortly after the intervention. Spinal surgery was a thankless job in the 19th century. The lack of adequate anesthesia forced surgeons to work as quickly as possible leading to the increased risk of errors, bleedings, suppurations, and lethal outcomes. Spinal surgery under these conditions was reasonably considered to be inhumane. De Quervain reported in 1908 that "... for 218 surgeries of this kind, recovery was observed in 13.8 %, improvement in 22.0%, treatment failure in 37.2 %, deterioration in 18.0 %, and death in 25.0 %" (W. Schmiden, 1935).

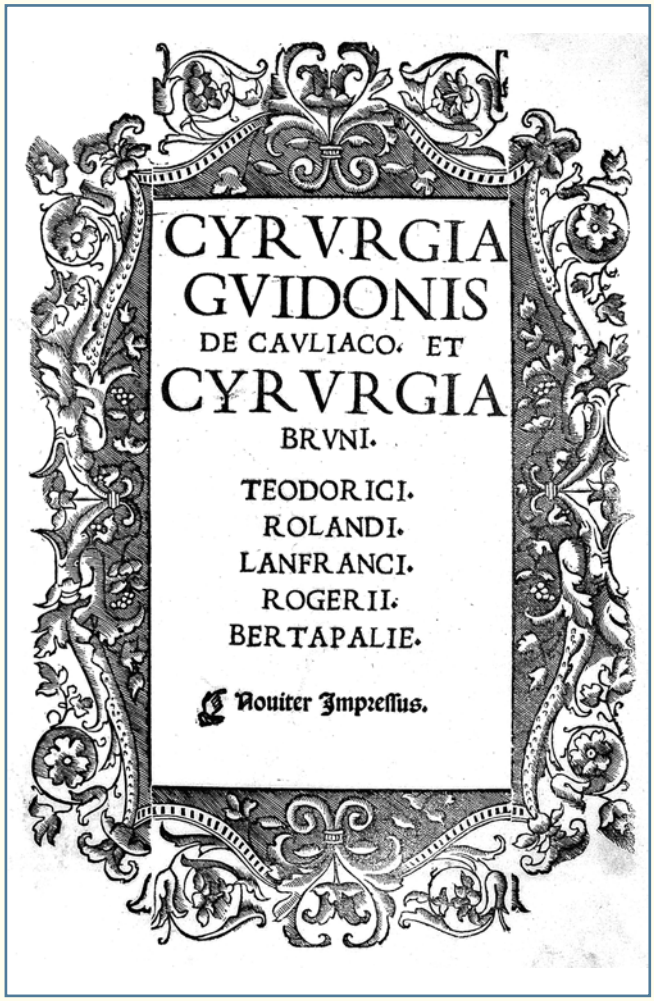
CYRVRGIA
GVIDONIS
DE CAVLIACO. ET
CYRVRGIA
BRVNI.
TEODORICI.
ROLANDI.
LANFRANCI.
ROGERII.
BERTAPALIE.
Nouiter Impressus.

Fig. 13
Cover of a book with the works of leading European surgeons [8]

Alban Gilpin Smith, an American physician, was the surgeon who performed the first successful laminectomy for spinal injury in Kentucky in 1829. The patient recovered, and the functionality of the spinal cord was restored. This surgical intervention is thought to be the first one following Paul of Aegina.

At the beginning of the 20th century, Pott's disease and the deformities associated with it were among the first surgically treated spinal abnormalities. Surgical debridement (opening a paravertebral abscess and washing its cavity with an antiseptic solution) described by Sir Percivall Pott (1713–1788) in 1778 remained the basis of treatment for this condition until the development of surgical stabilization methods.

Increased knowledge in anatomy, pathology, and methods of anesthesia (ether, chloroform) gave rise to the development of spinal surgery in the middle of 19th century. "Diagnosis and Treatment of Surgical Diseases of the Spinal Cord and its Membranes" by the New York surgeon Charles Elsberg (1916) can be considered the first guidance on spine surgery. The author not only described the technique of surgical interventions, but also presented spinal pathology as a particular medical specialty. He was known as "the father of spinal surgery".

The difficult relationship between neurosurgeons and orthopedists involved in spinal pathology treatment lasted for many years and has become proverbial. "Let the orthopedist place the metal implant, and the decompression is our business" – that was the philosophy of the 80s of the 20th century. However, since 1993, orthopedists and neurosurgeons have made the first steps towards working together. This union was due to a common enemy, implanted devices lawsuits.

Malgaigne (1806–1865) re-initiated practical fracture management by removing fragments of the spinous processes and spinal canal trepanation. The description of laminectomy by MacEwen (1848–1924) in 1886 was also influenced by Malgaigne's ideas. At the same time, Menard (1895–1934) described the technique of costotransversectomy in patients with tuberculous spondylitis complicated with paraplegia. This surgery was repeated in the USA by DeForest Willard (1846–1910). In the 1930s, Tuson and Malgaigne reported that the treatment for fractures by traction and kyphosis correction could contribute to the recurrence of paralysis. In 1824, Dr. Bell (1774–1842) was the first to describe in detail paralysis types that complicate spinal fractures. He differentiated between spastic and flaccid paralysis, and studied the condition of spinal shock and pelvic

Fig. 14
Repositioning a displaced vertebra: using body weight and spinal extension [8]

Fig. 15
Hilden Loop [10]

dysfunction. In 1891, Quincke performed the first lumbar puncture, or rachicentesis.

In 1898, Wagner and Stolper described the technique of "delicate" reposition of the fragments of damaged vertebrae in a large group of patients. Kyphosis was eliminated by axial traction combined with delicate pressure on its apex. In fact, this technique followed the recommendation of Hippocrates that demonstrated confirmed importance until the beginning of the 20th century. Wagner and Stolper supposed that patients after these procedures did not tolerate immobilization with a plaster jacket to maintain the obtained result; therefore, they preferred a hyperextension position with longitudinal traction for 4–6 weeks.

Since the beginning of the 19th century, studies (both in vivo and in vitro) have been conducted on the spine biomechanics. Thus, Weber (1795–1878) analyzed spine mobility in the clinic and using anatomical preparations. In 1876, Rauber investigated the strength of vertebral trabecular and cortical bone, and Messerer in 1880 proposed a specific device for the same purpose and analyzed the same data using cadavers.

Before the discovery of X-rays by Roentgen in 1895, the diagnosis of a spinal fracture remained a significant challenge. Malgaigne was sure that all fractures are accompanied by the paralysis. Kocher (1841–1917) in 1896 gave the opinion that this was true only for 90 % of observations. Because of the absence of appropriate diagnostics, most fractures were not identified unless they were accompanied by the development of neurological symptoms. Sudeck (1866–1945) was the first to propose a method for analysis of a spinal fracture using radiological images. In 1925, Davis performed the first radiological profile image of the spine (spondylograms were earlier performed only in the anteroposterior view) and 4 years later presented the first radiological images in two views demonstrating a vertebral body fracture. The number of complicated fractures was now estimated at 15–20 % of the total amount.

Surgical interventions were still rare in those years. Laminectomy was used as a method of spinal cord decompression. Bohler followed conservative treatment method suggesting that reposition was sufficient to eliminate the dislocation and to recover the shape of the spinal canal. Guttmann (1949) and Magnus (1931) held the same opinion thinking that paralysis was caused by a regressing hematoma or a tear of the spinal cord. Neither of these cases required surgical intervention. This

idea was based on the results of surgical treatment for complicated spinal fractures. In 1930, at the 5th congress of the German Surgical Society, Schmieden (1874–1946) provided data on the treatment of 3,014 patients; 1,105 of these had complicated spinal fractures. 217 patients (20 %) underwent surgical treatment. Functional recovery was observed in only 7.3 %, and 32.4 % of patients died after intervention.

Implementation of myelography into clinical practice in the 1930s allowed supporting laminectomy as a way to remove intervertebral disc tissue (Dandy, Zeno). This approach was used by Foerster to perform rhizotomy, cordotomy, and transection of the spinal cord in cases of chronic pain.

General anesthesia and aseptic technique marked the beginning of an era of effective surgery, including vertebral surgery. In 1844, Bell used laughing gas for anesthesia, and Morton used ether for the same purpose in 1848. In 1847, Semmelweis, a Hungarian obstetrician, introduced hand washing with chlorinated lime; this innovation helped to reduce the mortality rate among women in childbirth from 60 to 0.85 %. In 1856, Chassaignac proposed drainage of surgical wounds.

Alban Gilpin Smith (1788–1869), an American physician, was the first to remove an extradural tumor of the spinal cord in 1888.

All these events allowed spinal surgeons to progress to a new stage, with the implementation of ventral approaches to the spinal column being of great importance. In 1894, Chipault described a transoral approach; LeFort was the first who put it into practice in 1918 followed by Southwick and Robertson in 1957, Fang and Ong in 1962. Unfortunately, the interventions performed by Fang and Ong were characterized by a high mortality rate, in contrast to the results of Louis who has been using this approach since 1966 with no significant complications. The most widely used anterior approach to the cervical spine was developed by Cloward in 1958. In 1957, Cauchoix, Binet and Evrard proposed an anterior approach to the cervicothoracic junction, and in 1955, Hodgson did the same for the thoracolumbar spine.

The history of medicine as a whole, as well as of any particular medical discipline, is a tangle of searches and discoveries, inventions and disappointments, finds and losses, and most importantly, human lives. One can simply perform the duties – honestly, but without feeling. Whereas the other can search, create, make mistakes and inventions devoting their life to such search, although understanding the limitations of their knowledge and skills. Such individuals develop research teams and scientific schools, their opinions are listened with respect, students learn from them, and all this gradually brings any particular specialty and medicine as a whole to a new level. Such specialists accumulate their experience in large works that become guidance in a particular area of knowledge for years and decades. However, the time moves on, and new guideline books are required. There are probably quite a lot of such books, but not all of them cross state borders and become European or international manuals. We consider it reasonable to mention them in our “History of the Spine Surgery”, since their content describe the level of development of our specialty at a certain stage.

To be continued in the following issue.

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