1 History of Spinal Disorders

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Core Messages

- ✔ Paleopathological investigators have found clear evidence of spinal disorders in prehistoric times
- ✔ Full and accurate descriptions of spinal disorders and various treatment attempts survive from antiquity
- ✔ At the end of antiquity (7th century A.D.), Paulus of Aegina (625–690 A.D.) performed the first successful laminectomies
- ✔ During the whole of the Middle Ages, there was little progress in the diagnosis and treatment of spinal disorders
- ✔ At the end of the 18th century and the beginning of the 19th century, the first advanced attempts at spinal surgery were performed in Europe
- ✔ At the end of the 19th century, with the new techniques of anesthesia, radiology and aseptic surgery, more sophisticated and even more successful spinal surgery became possible
- ✔ In the middle of the 20th century, low back pain disability became an increasing socioeconomic problem
- ✔ In the 1970s and 1980s, powerful imaging systems (CT/MRI) improved the diagnosis for spinal disorders but also led to some overdiagnosis of spinal disorders
- ✔ In the 1980s and 1990s, spinal instrumentation became widely available and enabled even complex spinal disorders to be tackled
- ✔ During the 20th century, the focus on spinal disorders dramatically changed: at the beginning of the 20th century spinal disorders were predominantly caused by infectious diseases; nowadays the focus is more on degenerative spinal disorders
- ✔ At the beginning of the 21st century, spinal surgery has become more evidence based, but it is still technology driven in many areas

A Brief Etymology

Nicholas Andry coined the word "*orthopaedic*" in 1741

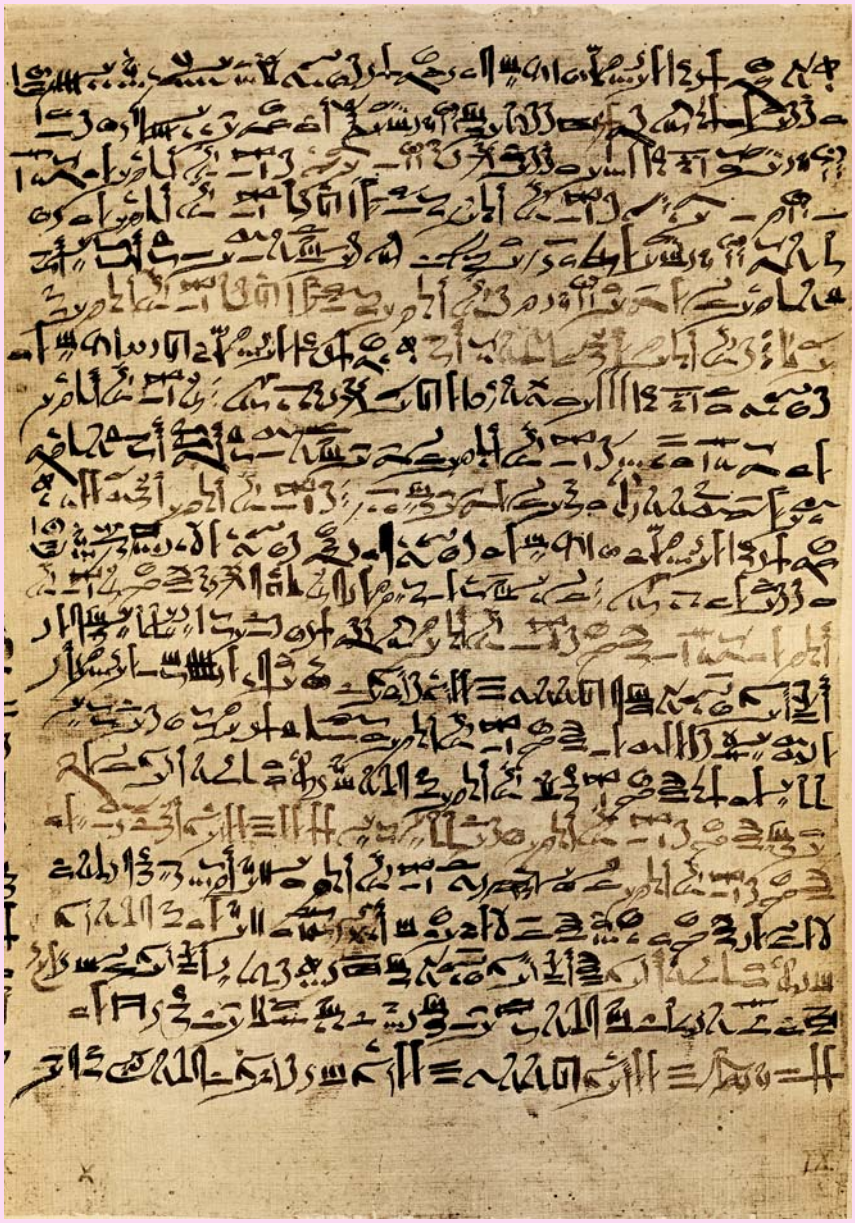
The French pediatrician Nicholas Andry (1658–1742), considered the father of orthopedics, coined the word "*orthopaedic*", which is made up of two Greek words, "*orthos*", meaning straight, and "*paidion*", meaning child (Fig. 1a) [3]. The term "*orthopaedic*" was used for the first time in the epoch-making textbook of Andry published in 1741.

Andreas Vesalius coined the word "vertebra"

The origin of the word **spine** derives from the Latin word "*spina*" meaning "backbone". The word **vertebra**, first found in the medical texts of Celsus (34 B.C.–14 A.D.), a Roman encyclopedist, derives from the Latin word "*vertebra*", which is related to the Latin verb "*vertere*" meaning "to turn". The great anatomist Andreas Vesalius (1514–1564) finally introduced the word "vertebra" as an anatomical term [116].

The Greek word "scoliosis" means curvature

The term **scoliosis** is derived from the Greek word "*scolios*" meaning "curvature" and was coined by the Greek physician Galen of Pergamon (130–200 A.D.) (Fig. 1b) [36]. Nowadays, it is used to describe a specific clinical condition consisting of lateral deviations of the spine associated with vertebral rotation.



Historical Case Introduction

This papyrus shows Column X of the *Edwin Smith Surgical Papyrus*, written in hieratic script, which encompasses a description of a spinal injury. The *Edwin Smith Surgical Papyrus* dates back to 1550–1500 B.C. and is therefore the oldest known written evidence of spinal injuries [10]. This medical papyrus is an outstanding witness of a very accurate and rational medicine in Old Egypt foremost in traumatology. The papyrus reveals an astonishing knowledge of human anatomy at the Pharaonic time in Egypt:

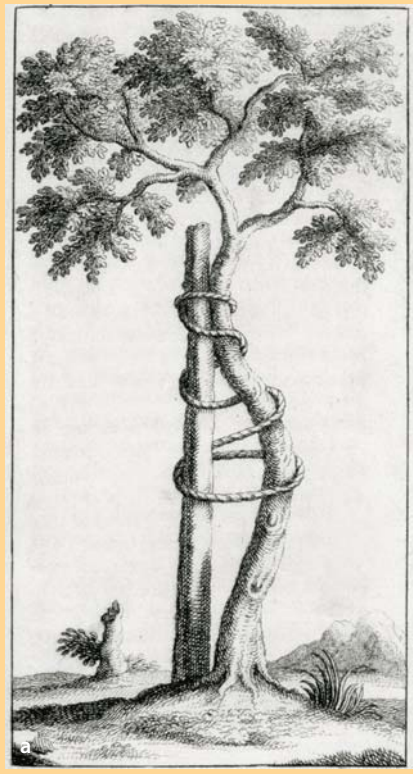
Case 29: Instruction concerning a gaping wound of vertebra of his neck

Examination: 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.

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 the fresh meat the first day. Now afterward moor (him) at his mooring stakes until the period of his injuries passes by.

Translation by the famous American Egyptologist J.H. Breasted (1930).



a

b

Figure 1. The roots

a This drawing of scoliosis therapy in Nicholas Andry's (1658–1742) epoch-making textbook *L'Orthopédie* (1742) serves as a general symbol of orthopedics. **b** Galen of Pergamon (130–200 A.D.).

Kyphosis is also derived from the Greek word "*kyphos*" meaning "hunchback" or "bent". Galen of Pergamon [36] first coined this term in medical language. The term **lordosis** belongs also to the Greek word family and is derived from the Greek word "*lordos*" standing for "forward curving". Galen of Pergamon first used the word "lordosis" as a medical term [36]. **Sciatica** is of Greek origin and is derived from the word "*ishion*" standing for hip, buttocks, sacrum, loin and also upper limb. Since the time of Hippocrates of Cos (460–370 B.C.), this term has related to pain syndrome of the lower back and the upper parts of the lower limbs [57].

The Greek word "*kyphos*" means "hunchback"

The term **spondylolisthesis** is originally derived from two Greek words, "*spondylos*" for spine and "*(o)listhesis*" for forward gliding. Therefore, it means the "(forward) slipping of the spine". In 1854, Herman Friedrich Kilian (1800–1863) coined the term "spondylolisthesis" [64].

The Greek word "*olisthesis*" means "forward gliding"

Spondylophyte is composed of two Greek words, "*spondylos*", standing for spine, and "*phytein*", a Greek verb meaning "to grow". The whole term means "spinal outgrowth". The term "isthmic" frequently used in spinal surgery is derived from the Greek word "*isthmos*", which means in its natural sense "isthmus" and also "strait or narrow" [59].

Spinal Anatomy and Physiology

Herophilus and later Galen studied spinal anatomy

Successful modern spine surgery only became possible because of the large body of knowledge of anatomy and physiology which had been acquired. The first steps were already taken in antiquity: Herophilus of Chalcedon (circa 300 B.C.), known as the father of anatomy, and later **Galen of Pergamon** (130 – 200 A.D.) made the first observations on the nervous system and the spine. Galen identified the number of vertebrae in each segment of the spinal column, and described the ligamentum flavum as a ligamentous structure distinct from the underlying dura and pia mater. He was also able to correlate neurological findings with a specific spinal level, because he performed frequent experiments on primates.

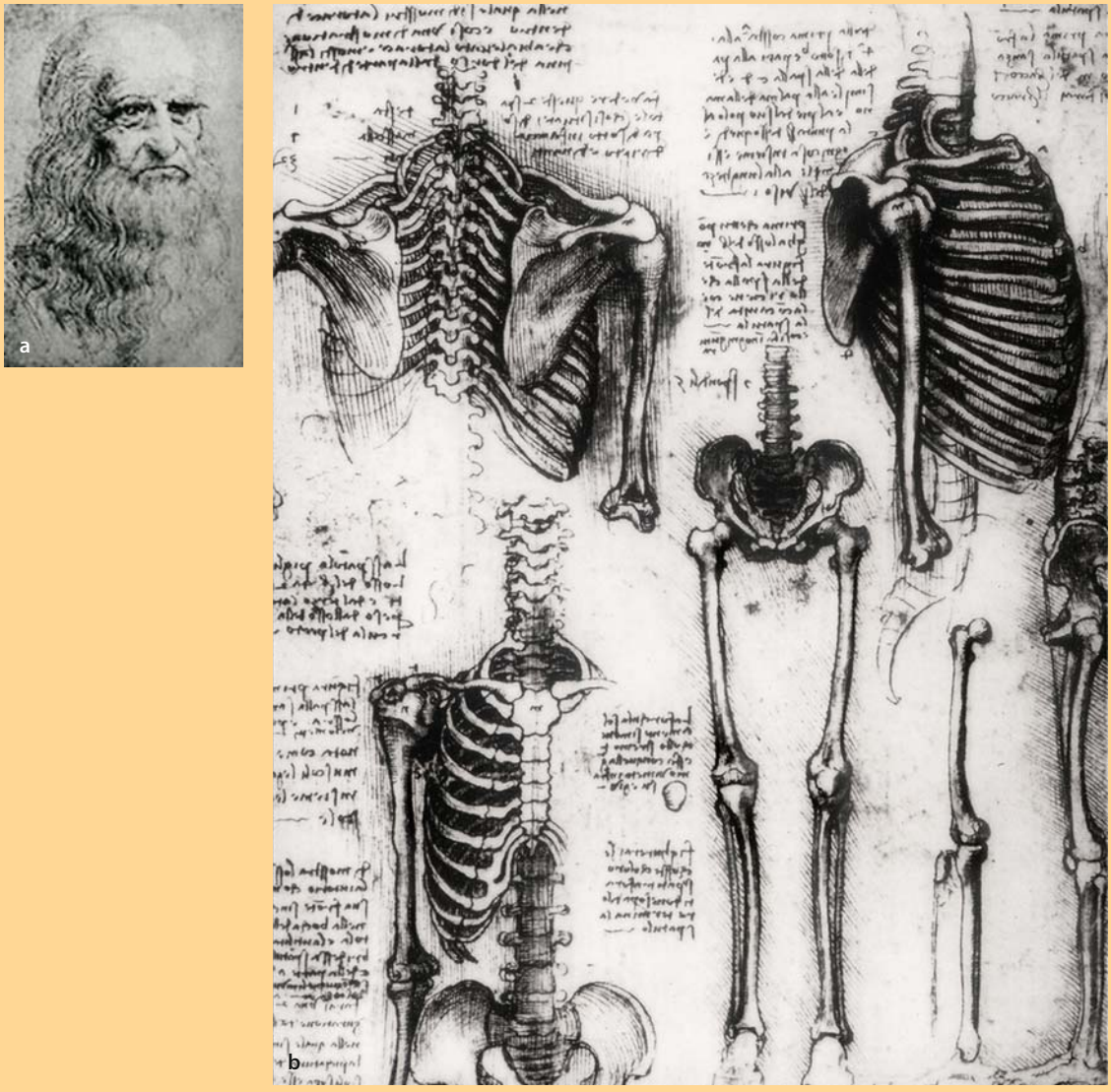


Figure 2. Spinal anatomy and physiology

a Leonardo da Vinci (1452 – 1519). b This sketch drawn by Leonardo da Vinci is the first correct depiction of the human spine.

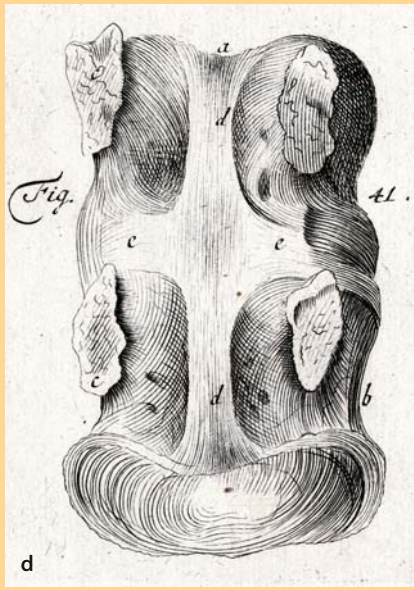


Figure 2. (*Cont.*)

c Andreas Vesalius (1514 – 1564). **d** Josias Weitbrecht's (1702 – 1747) *Syndesmologia* (1742) precisely described the spinal ligaments.

During the Middle Ages, no progress was made in the understanding of spinal anatomy.

In the Renaissance, **Leonardo da Vinci** (1453 – 1519) was probably the first to accurately describe the spine with the correct curvatures, articulations and number of vertebrae (Fig. 2a, b). Sadly, he never published his anatomical drawings and therefore his anatomical discoveries remained unknown for centuries.

Leonardo da Vinci's drawings are the first to show the spinal anatomy

Andreas Vesalius (1514 – 1564) broke with the Galenic anatomy and presented the most integrated and accurate anatomy (Fig. 2c). He is therefore credited with describing the spinal anatomy in a modern sense [116]. By publishing the cutting-edge anatomical textbook *De Humani Corporis Fabrica Libri Septi*, Vesalius became the founder of modern spinal anatomy in 1543.

Andreas Vesalius (1514 – 1564) is the founder of modern spinal anatomy

The Dutch anatomist **Gerard Blasius** (1625 – 1692) wrote the first significant work on spinal cord anatomy. In his text *On the Anatomy of the Spinal Nerves* (*Anatome Medullae Spinalis et Nervorum indeprovenientium*) (1666), Blasius was the first to provide a demonstration of the origin of the spinal nerve roots and a differentiation between the gray matter of the spinal cord [6].

Blasius wrote the first significant work on spinal cord anatomy

In *De Motu Animalium* (*On the Movement of Animals*) written by Giovanni **Alfonso Borelli** (1608 – 1680), a professor of mathematics and the father of biomechanics, the intervertebral disc was described for the first time as exhibiting viscoelastic properties (published posthumously in 1688) [8].

Borelli first recognized the viscoelastic intervertebral disc behavior

The German physician and anatomist Albrecht von Haller (1708 – 1777) worked in Berne, and is credited as the founder of modern physiology. He illustrated the blood supply of the spinal cord with an accuracy that is still unsurpassed.

The Italian physician **Domenico Felice Antonio Cotugno** (1736 – 1822), a professor of medicine at the University of Naples, was the first to fully describe the cerebrospinal fluid and its circulation in his epoch-making *Commentary on Nervous Sciatica* in 1764 [21].

Cotugno first described the cerebrospinal fluid

At the same time in 1742, the German anatomist **Josias Weitbrecht** (1702 – 1747) published his monumental work on human ligaments, *Syndesmologia Sive Historia Ligamentorum Corporis Humani*, which for the first time also gave a concise and accurate description of the spinal ligaments (Fig. 2d) [121]. Weitbrecht is also credited with providing a very concise description of the intervertebral disc for his time.

"Centers of feeling" were thought to be located in the spinal cord

At the beginning of the 19th century, it was still believed that some parts of the spinal cord contained the "centers of feeling". Furthermore it was believed that the spinal cord consisted of bundles of nerve fibers grouped into columns. After the microscope entered clinical and pathological practice, the cellular contents of the gray matter were identified, and since then there have been steady advances in our understanding of the spinal cord.

Anesthesia and Supportive Techniques

An invasive and effective spinal surgery would not have been possible without major advances in anesthesia and supportive techniques such as antisepsis, antibiotics and diagnostic imaging.

Laughing Gas, Chloroform and Cocaine

Wells first narcotized patients with laughing gas

In 1799, the English chemist **Sir Humphrey Davy** (1778 – 1829), a former scholar of Joseph Priestley, discovered that pure nitrous oxide was respirable. He tried the effect of this substance first on himself and recommended that nitrous oxide ("laughing gas") could be useful for narcotizing patients during operations. In 1844, it was the American dentist Horace Wells (1815 – 1848) who tried extracting teeth by narcotizing patients with laughing gas.

Morton popularized narcotics for surgery

William Thomas Green Morton (1819 – 1868), a former colleague of Horace Wells, made the use of narcotics for surgery popular. On 16 October 1846, Morton presented his narcotizing method to the public in the operating theater of the Massachusetts General Hospital in Boston (Fig. 3a).

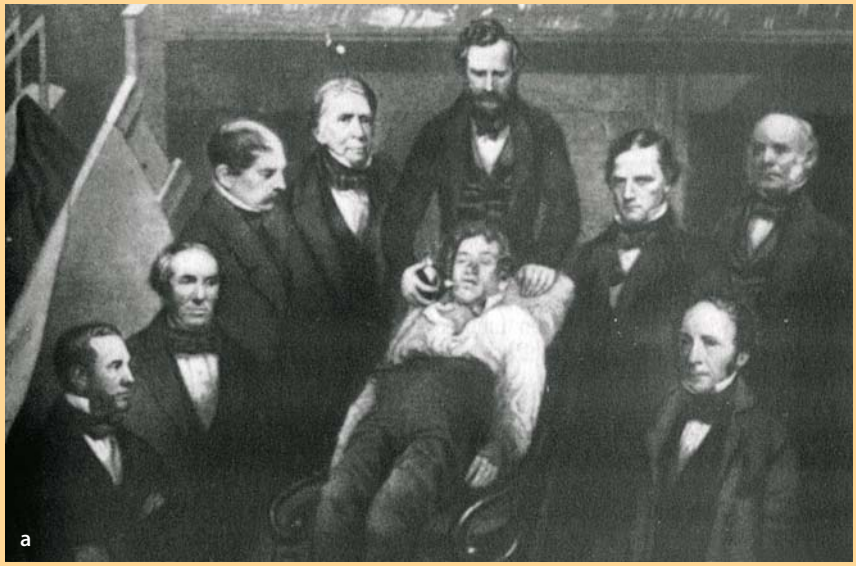
Bier first performed lumbar anesthesia

Further improvements were made by Sir James Simpson, an English gynecologist and obstetrician, who introduced chloroform as a narcotizing agent after a large series of heroic self-experiments. In 1884, the Austrian ophthalmologist Karl Koller (1875 – 1944) first used cocaine for narcotizing mucous membranes. In 1885, the young American surgeon **William S. Halstead** (1852 – 1922), who was enthusiastic about the effect of cocaine and also addicted to it, developed the first intravenous anesthesia block with cocaine. The world's first lumbar anesthesia using cocaine as agent was performed in 1898 by the German surgeon **August Bier** (1861 – 1949). He was inspired by the lumbar puncture technique introduced by the German physician Heinrich Quincke (1842 – 1922) 7 years earlier [5]. In 1894, the famous neurosurgeon **Harvey Cushing** (1869 – 1939) introduced the narcotic protocol for better surveillance of patients during the narcotizing procedure.

Antisepsis and Antibiotics

Infections were thought to be a divine punishment

For a long period of history, infections were thought to be a divine punishment. It was a contemporary of Cesar, Marcus Terentius Varro (116 – 27 B.C.), who assumed in his work on rural labor *Rerum Rusticarum* that infections are caused by very small animals, which he called "**contagiatum animatum**" (infectious animals). In 1546, the Italian Renaissance physician **Girolamo Fracastoro** (1478 – 1553), who coined the name "**syphilis**", postulated in his famous work



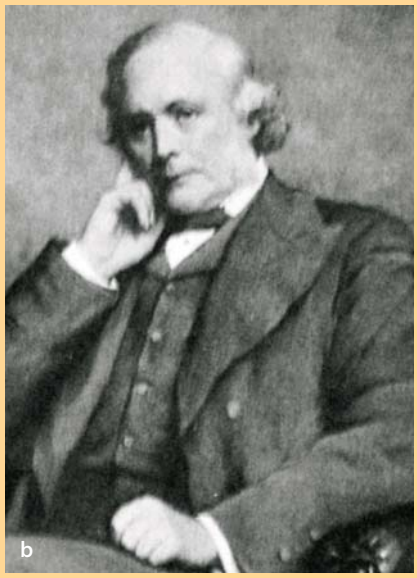


Figure 3. Anesthesia and supportive techniques

a Public demonstration of a narcotization by William Thomas Green Morton (1819 – 1868), Massachusetts General Hospital, Boston (16 October 1846). b Joseph Lister (1827 – 1912). c William Conrad Roentgen (1845 – 1923).

On Infection, Infectious Diseases and Their Cure (*De Contagiosis Morbis Eorumque Curatione*) that infections are not only transmitted by air but also by human contact. The Dutchman Antony van Leeuwenhoek (1632 – 1724) gave the first evidence of microbes in his work on the microscope. Finally, it was the German physician and bacteriologist **Robert Koch** (1843 – 1910) who showed that specific germs are responsible for specific infections, for example, *Mycobacterium* for tuberculosis or anthrax bacillus for anthrax disease.

Koch discovered that *Mycobacterium* is responsible for tuberculosis

The famous English surgeon **Joseph Lister** (1827 – 1912), who was the son-in-law of James Syme (1799 – 1870), famous for his ankle amputation, introduced aseptic surgery in 1866 (Fig. 3b) [70, 71]. Based on studies of the French microbi-

Lister first introduced aseptic surgery

ologist **Louis Pasteur** (1822 – 1895), he believed that infections were transmitted by air. Therefore, he proposed irrigation and disinfection of the operation field by using a weak solution of carbolic acid [71]. He called his procedure "**carbolization**".

The first steam sterilizer was installed in 1882

In 1882, the German surgeon **Friedrich Trendelenburg** (1844 – 1924) was inspired by the discovery of Robert Koch, that carbol acid is not able to kill germs in contrast to steamed air. Therefore, he installed the world's first steam sterilizer in his clinic in Bonn. Finally, it was the German physician Curt Schimmelbusch (1860 – 1895) who improved the technique of sterilization and popularized it.

Halstead introduced rubber gloves

A further great step towards aseptic surgery was made by **William S. Halstead** (1852 – 1922) working as professor of surgery at Johns Hopkins University. In 1880, he introduced rubber gloves because his fiancée, who was working as an operating nurse at the same hospital, had developed a severe skin irritation due to exposure to mercury solution.

Fleming discovered penicillin

The Scottish bacteriologist **Alexander Fleming** (1881 – 1955) accidently discovered that the mold *Penicillium notatum* had a bacteria-toxic effect on *Staphylococcus* cultures. After several experiments he was able to extract a liquid substance, which he called penicillin, because of the name of the mold, *Penicillium notatum*, and he published his results in 1929.

However, there was no initial response to his report. It was only in the late 1930s that the pathologist Howard Floery (1898 – 1968) and the biochemist Ernst Chain (1906 – 1979) repeated and confirmed Fleming's work while searching for effective antagonists against microorganisms. In 1945, Fleming, Florey and Chain received the Nobel Prize for their work.

Diagnostic Imaging

Roentgen accidentally discovered X-rays in 1895

Without the appropriate imaging modalities, the development of a comprehensive treatment regime for spinal disorders would not have been possible. In 1895, the physicist **William Conrad Roentgen** (1845 – 1923) accidently discovered the relevance of X-rays for medical imaging while he was performing experiments on a cathode beamer (Fig. 3c). In 1896, he published his discovery and X-rays became immediately popular [99]. He was honored by the Nobel Prize in 1901. The famous American neurosurgeon **Walter E. Dandy** (1886 – 1946) introduced air myelography for spinal imaging in 1918 [24].

The first brain CT scan became possible in 1971

A revolutionary step forward in diagnostic assessment of spinal disorders was the introduction of computed tomography (CT) in the early 1970s. This imaging device was a step-by-step development. Three individuals contributed to this landmark invention, i.e. the English engineer **Godfrey N. Hounsfield**, the American physicist **Allan M. Cormack** and the American neurologist **William Oldendorf**. Oldendorf first suggested that by means of CT brain tumors can be diagnosed. The first brain image of a patient with a brain cyst was made in 1971. In 1974, the American **Raymond Damadian** (1936 –) patented an imaging device using principles of the nuclear magnetic resonance phenomenon, first described by the Swiss physicist and Nobel Prize winner **Felix Bloch** (1905 – 1983) in 1952.

The first brain MR image became possible in 1979

The first brain scan by MR imaging became possible in 1979.

Scoliosis

Since the beginning of written history, scoliosis has been a major concern in medical texts. The clinical image of scoliosis very much impressed ancient physicians and treatment remained poor for centuries. Even today, treatment is unsatisfactory since correction of scoliosis is not possible without spinal fusion.

Pathogenesis

During **antiquity** and the **Middle Ages**, the pathogenesis of scoliosis was not clear and it has still not been unraveled today. It was often supposed that the spinal deformities were caused by luxation of spinal elements. Therefore, spinal deformities were called "**spina luxata**". No distinctions were made between scoliosis, kyphosis, and a gibbus. Treatment regimes did not differentiate between these entities. The first picture of a scoliotic spine (Fig. 4a) appeared in the important surgical textbook of the German surgeon Guilhelmus Fabricius Hildanus (1560 – 1634) in 1646 [56].

Spinal deformities were called "spina luxata" without distinction between scoliosis and kyphosis

It was the Frenchman **Jean Méry** (1645 – 1722) who first suggested that both lateral deviation and rotation of the spine are responsible for scoliosis [84]. When research on scoliosis started, it was commonly believed that muscle dysfunction was the cause. Only after Pott's description of spinal tuberculosis was a distinction was made between spinal deformities caused by tuberculosis and spinal deformities of other etiologies. During the second half of the 19th century, research focused on the spinal osseous changes in patients suffering from scoliosis.

Méry first realized the importance of spinal rotation for scoliosis

The French surgeon Sauveur-Henri Victor Bouvier (1799 – 1877) is credited as the first to further differentiate between rickets caused scoliosis and idiopathic scoliosis [9].

Assessment

Before the advent of X-rays, it was very difficult to measure scoliosis and treatment outcome. The French surgeon Jacques-Mathieu Delpech (1777 – 1832) made plaster molds of his scoliosis patients to assess the extent of the curvature. In 1850, an employee of **Johann Julius Bühring** (1815 – 1855), head of an orthopedic clinic in Berlin, invented a measuring machine that made it possible to depict correctly a spinal curvature. The measuring machine consisted of a glass plate with engraved squares on which a sheet of paper was fixed. The patient was placed in front of the machine. Defined parts of the patient's back were marked and then transferred onto the paper by tracing.

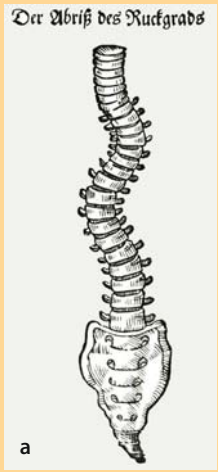
Bühring invented a scoliosis measuring machine

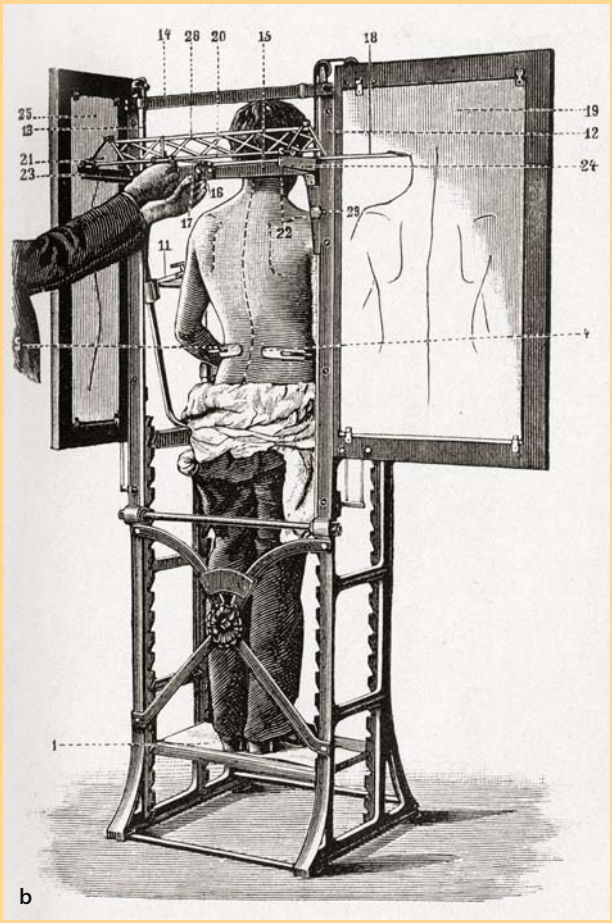
In 1885, the Swiss pediatrician and physician **Wilhelm Schulthess** (1855 – 1917), founder of the first orthopedic clinic in Zürich, constructed a measuring machine, based on the principles of Bühring. This apparatus allowed the depiction of a three-dimensional representation of the scoliosis [107]. Schulthess also invented stereotactic machines to produce calibrated corrections and to measure rotation (Fig. 4b). In 1906, he published a very comprehensive book on scoliosis, which served for many years as a reference textbook [108]. With the advent of X-ray machines at the beginning of the 20th century, the American orthopedic surgeon **John Robert Cobb** (1903 – 1967) introduced the **"Cobb angle",** which was popularized by the American orthopedic surgeon Robert Korn Lipmann (1898 – 1969) in 1935 [19].

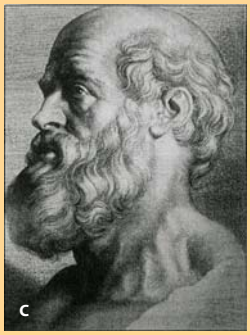
Schulthess constructed a 3D measuring machine for scoliosis

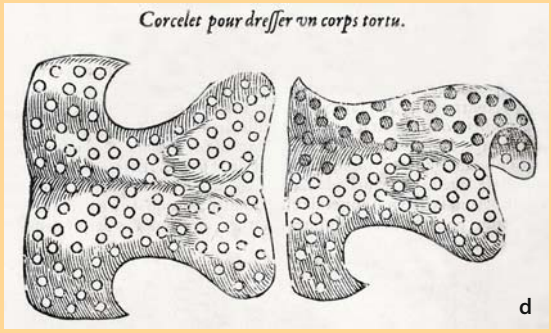
The American surgeon **Joseph Charles Risser** (1892 – 1982) was a great advocate of early scoliosis treatment and frequently used plaster casts as a non-operative treatment. He also thought that it was better to operate on patients at an early age rather than waiting for the development of large curves. He popularized the assessment of the osseous fusion of the iliac crest apophysis as an estimate for the child's growth potential, which became later known as the **Risser sign** [98].

Risser first assessed the growth potential by iliac crest apophysis ossification









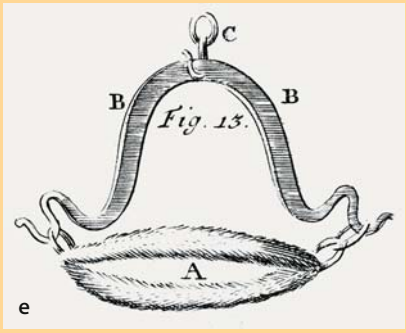
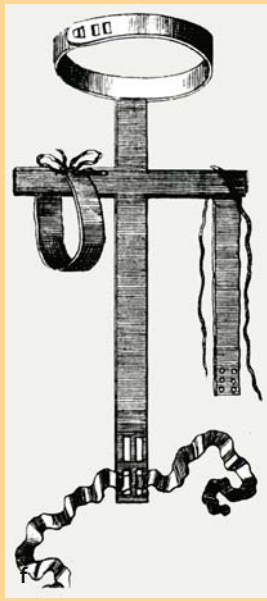
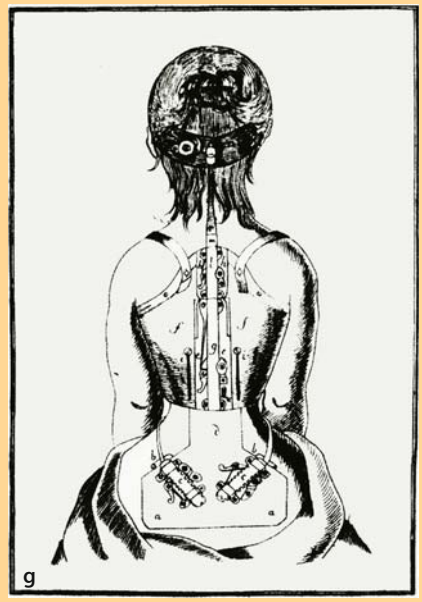
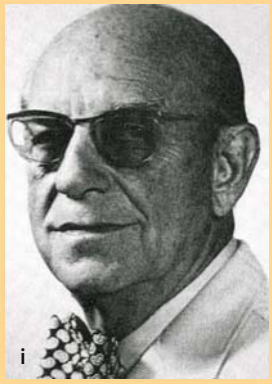


Figure 4. Scoliosis

a The first picture of a scoliotic spine published by Guilhelmus Fabricius Hildanus (1560–1634). **b** Measuring apparatus for scoliosis constructed by the Swiss physician and pediatrician Wilhelm Schulthess (1855–1917) in 1885. **c** Hippocrates of Cos (460–370 B.C.). **d** The scoliosis brace made of iron plates by Ambroise Paré (1510–1590). **e** The "Glisson swing" developed by Francis Glisson (1616–1691).







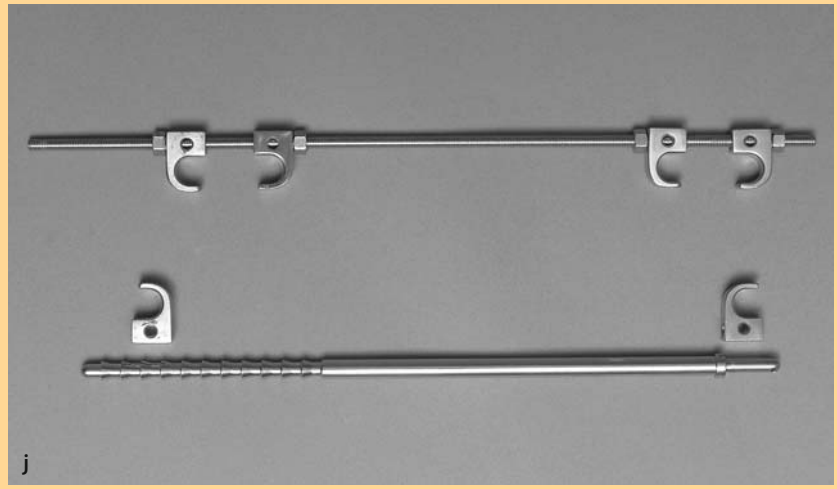


Figure 4. (*Cont.*)

f Heister's iron cross invented by the German surgeon Lorenz Heister (1683–1758). **g** *"Appareil du jour"* for scoliosis patients developed by Jean-André Venel (1740–1791). **h** *"Appareil de la nuit"* developed by Venel. **i** Paul Randall Harrington (1911–1980). **j** Harrington hooks and rods for the treatment of scoliosis.

Non-operative Treatment

An ancient Indian epic first described scoliosis treatment (3500–1800 B.C.)

Probably the first description of the treatment of spinal deformity is recorded in the *Srimad Bhagwat Mahapuranam*, an ancient Indian epic written between 3500 and 1800 B.C. [111]. There, the Indian god Lord Krishna cures the hunchback of one of his female devotees named Kubja by applying axial traction.

Hippocrates invented the first traction table

The state of the art medical textbook of antiquity *On Articulation* (part of the monumental and famous *Corpus Hippocraticum*) was probably written by the Greek physician Hippocrates (Fig. 4c) of Cos (460–370 B.C.) and his scholars. In this text collection numerous descriptions concerning normal and abnormal spinal curvatures can be found [57]. However, spinal deformities provoked by tuberculosis were not differentiated from true scoliosis. The treatment was poor and consisted of the famous "**Traction Table**" also known as the "**Hippocratic**

bench" or "*scamnum*" (the Latin expression for traction table) with which patients were stretched, both horizontally and with underarm and leg distraction in suspension. In later times, only little progress was made regarding the etiology and treatment of spinal deformities.

Spinal deformities were thought to result from spinal luxation

Even at the end of the Middle Ages, the common belief was that a spinal deformity was caused by a spinal luxation. Therefore, such deformities were called "**spina luxata**" and the term included every kind of scoliosis and kyphosis. In 1544, the famous Italian surgeon **Guido Guidi** (1508 – 1569) proposed treating such spinal deformities by using the techniques of a traction table as introduced by Hippocrates and elaborated by Oribasius (325 – 405 A.D.) [91]. The surgical textbook *Chirurgia è Graeco in Latinum Conuersa*, written by Guido Guidi (alias Vidus Vidius) contains many illustrations depicting different types of extension machines also known as traction tables [42].

Paré (1510 – 1590) introduced a brace for scoliosis treatment

A less cruel method of treating spinal deformities was developed by **Ambroise Paré** (1510 – 1590). The father of French surgery also reintroduced the ligature of vessels. He suggested treating scoliosis by an iron plate brace (Fig. 4d) [79], which had to be changed in size during the acceleration phase of child growth at least every 3 months.

Blount introduced the Milwaukee brace

A revolutionary step forward in scoliosis bracing was made by the American orthopedic surgeon **Walter Putnam Blount** (1900 – 1992), who was devoted to scoliosis and its treatment. In 1945, Blount introduced the so-called "Milwaukee brace", which is still in use today [7].

Glisson developed a swing suspension by the head and armpits

The English physician **Francis Glisson** (1616 – 1691), professor of medicine for over 41 years at Cambridge, wrote extensively on rickets in his pioneering book *On Rickets* (*De Rachitide, Sive Morbo Puerili, qui Vulgo The Rickets Dicitur Tractatus*) in 1650. He assumed that scoliosis was caused by rickets and that the pathomechanism was based on the unequal and asymmetric bone growth of the spine [39]. Therefore, he developed a swing suspension by head and armpits known as the "**English swing**" or "**Glisson swing**" (Fig. 4e) [39].

Heister's iron cross served as a prototype for later scoliosis braces

Since then, many spinal extension machines have been developed and propagated, for example, the extension chair introduced by the French surgeon Pierre Dionis (birth date unknown – 1718) in 1707 [30]. In his *Cours d'Opération de Chirurgie*, **Pierre Dionis** also mentioned for the first time the use of an iron cross for correcting spinal scoliosis. The cross became well known as **Heister's cross**, because the German surgeon **Lorenz Heister** (1683 – 1758) first depicted the iron cross in his textbook of surgery [49, 50]. Heister's cross was used as a kind of scoliosis brace and served as a prototype for later scoliosis braces (Fig. 4f).

The book "*Orthopedia*" made Nicholas Andry the father of modern orthopedics

In 1741, the French pediatrician **Nicholas Andry** (1658 – 1742) published his epoch-making and pioneering textbook "***Orthopédie***" and became the father of modern orthopedics [3]. A great part of his book dealt with the description of scoliosis prevention, giving especial attention to sitting and postural habits and recommending for example physical exercises and a specially designed chair.

Venel invented a spinal extension machine (orthopedic bed)

Influenced by the Enlightenment, the Swiss orthopedic and former obstetrician **Jean-André Venel** (1740 – 1791) founded the world's first orthopedic hospital in the small Swiss town of Orbe in 1780. He developed a new treatment regime for spinal deformities in 1785 [113]. Venel believed that two kinds of procedures were suitable: first axial extension along the spine and second application of forces in transverse planes at the region of deviation. Furthermore, he was convinced that the treatment of scoliosis does not tolerate any interruption. Based on such ideas, he developed a brace for daily activities called an "***appareil du jour***" and an **orthopedic bed**, an extension machine, for the night called an "***appareil de la nuit***" (Fig. 4g, h). Venel's invention resulted in a hype boom during the fol-

lowing half century and all sorts of different orthopedic beds were developed. In 1829, Johann Friedrich Diefenbach (1792 – 1847), one of the most important orthopedic surgeons of the 19th century in Germany, catalogued the various extension beds and chairs, filling 70 pages [61].

Scoliosis Surgery

Tenotomy and myotomy was the early but unsuccessful treatment for severe scoliosis

In the first half of the 19th century, tenotomy and myotomy were used for severe scoliosis both because of the prominent paraspinal muscles and the muscle dysfunction theory as outlined above. A very prominent advocate of tenotomy was the French surgeon **Jules René Guérin** (1801 – 1886), who developed this technique in 1835 and treated 1349 patients [41].

After the initial enthusiasm, some terrible outcomes were experienced by patients and the method was abandoned. It may be of interest that the controversy over this technique was one of the first incidences of doctors criticizing and attacking each other in print and in court.

Hibbs performed the first spinal fusion for scoliosis

In 1911, the American surgeon **Russel A. Hibbs** (1869 – 1933) fused the spine for tuberculosis and suggested extending this method also to scoliosis, as explained in more detail below [46]. He first performed an in situ fusion in 1914 and later corrected the curve with a cast until fusion had occurred. He gave several reports of his technique and advocated a long fusion before the deformity became severe [53, 54].

After the first successful instrumentations of the spine performed by **W.F. Wilkins** (1845 – 1935) [122] and a little bit later by **Berthold Ernst Hadra** (1842 – 1903) [45], many efforts were made to stabilize the spine with instrumentation, e.g. by the German orthopedic surgeon **Fritz Lange** (1864 – 1952) [69].

Harrington developed a milestone spinal instrumentation system

Finally, however, it was the American orthopedic surgeon **Paul Randall Harrington** (1911 – 1980) who succeeded in developing an appropriate system for scoliosis instrumentation (Fig. 4i) [37]. This spinal instrumentation system known as "Harrington instrumentation" consisted of stainless steel hooks and rods, which allows the correction of the spinal curvature by distraction (Fig. 4j). Harrington invented this spinal instrumentation system after a severe poliomyelitis epidemic in the late 1950s. He popularized spinal instrumentation in his milestone paper *Treatment of Scoliosis: Correction and Internal Fixation by Spine Instrumentation* published in 1962 [47]. The early technique consisted only of instrumentation. Fusion was later added because of the initial poor outcome.

Dwyer developed the first anterior spinal instrumentation system

In 1969, the Australian surgeon **Alan Frederick Dwyer** (1920 – 1975) introduced the first anterior spinal compression system for scoliosis correction [31].

Luque introduced segmental spinal correction

More than a decade later the Mexican surgeon **Eduardo Luque** developed a posterior segmental fixation system, which allowed segmental stabilization without the need for a postoperative cast [74].

Cotrel and Dubousset introduced the concept of spinal derotation

In 1984, the French surgeons **Yves Cotrel** and **Jean Dubousset** introduced their posterior derotation system, a system consisting of stainless steel pedicle screws, rods, hooks and transverse traction devices [22]. By means of this system, it was possible not only to address lateral deviation of the spine but also apical rotation and thereby improve the sagittal profile of the spine. Cotrel-Dubousset instrumentation started a new area in spinal surgery.

Juvenile Kyphosis

Scheuermann first described juvenile kyphosis

The Danish radiologist **Holger Werfel Scheuermann** (1877 – 1960), head radiologist at the Cripple's Hospital in Denmark, first described juvenile kyphosis in his thesis which he presented to the University of Copenhagen in 1921. Scheuermann

reported on a series of 105 adolescent patients (80 % males) suffering from a sagittal curvature but with only a minimal coronal deviation [105]. Thus, he postulated a new group of spinal disorder, which begins during puberty and is associated with a genuine thoracic kyphosis. Initially, his thesis was rejected by the university committee. In 1957, he was finally awarded an honorary doctorate in recognition of his work. Nevertheless the entity became known as **Scheuermann's disease**.

The German pathologist **Christian George Schmorl** (1891 – 1932) performed pathoanatomical studies on more than 5000 spinal specimens which he later published in his famous book *The Human Spine*. Schmorl first described the intercorporal disc prolapses known nowadays as **Schmorl's node** [106], which are frequently seen in juvenile kyphosis.

Spondylolisthesis

An Obstetrical Problem

Herbiniaux described the first case of spondylolisthesis

Spondylolisthesis must have been observed in ancient times but was probably first mentioned in 1782 by the Belgian surgeon and obstetrician **G. Herbiniaux** (1740 – end of the 18th century). He claimed that it interfered with childbearing and resulted in the death of both mother and child [52].

Kilian coined the term "spondylolisthesis"

In 1854, **Herman Friedrich Kilian** (1800 – 1863) coined the term "spondylolisthesis", which means the "downward gliding of the spine" [64].

In 1882, **Franz Ludwig Neugebauer** (1856 – 1914), an obstetrician in Warsaw, published a monograph on spondylolisthesis in which he described exactly the clinical features of spondylolisthesis also in relation to obstetrical problems of a narrowing birth canal in patients with severe spondylolisthesis [89]. In 1976, **Wiltse, Newmann and Macnab** were the first to classify spondylolisthesis into five categories: dysplastic, isthmic, degenerative, traumatic and pathological types [124].

Surgery

In 1893, Sir **William Arbuthnot Lane** (1856 – 1938), who became famous for introducing the "no touch" or fully instrumental technique of surgery, performed a decompressive laminectomy on a 34-year-old woman who suffered from progressive gait disturbance, leg weakness and loss of sensation in the lower limbs. During the operation, he found a forward slipping of the body and neural arch of L5 on the sacrum without any defect [67].

The first anterior interbody fusion was performed by Burns

In this context, the history of the anterior interbody fusion technique should briefly be reviewed because this surgical technique was first successfully performed in a 14-year-old boy with spondylolisthesis by the English surgeon Burns in 1933 [14]. Burns' technique consisted of driving an autologenous tibia dowel through the fifth lumbar vertebra into the sacrum (Fig. 5).

Lane and Moore published the first routine series of anterior interbody fusion in 1948 and shortly after Harmon brought his series to the public in 1950 and 1960 [46, 68]. Since then, many modifications have been made. In the late 1950s, the American surgeon Humphries and his team first introduced the plate system for anterior interbody fusion, which consisted of an especially designed compression plate primarily for the lumbosacral joint that was fastened onto the anterior surface of the vertebra by screw [60]. At the same time, the orthopedic surgeon **Arthur Ralph Hodgson** (1915 – 1993), head of the Orthopedic and Trauma Unit at the University of Hong Kong, developed an anterior fusion by using bone grafts for tuberculosis treatment as explained in more detail below

Hodgson developed an anterior fusion technique with bone graft insertion

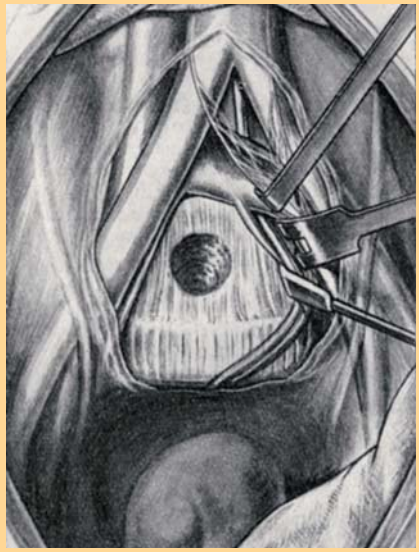


Figure 5. Spondylolisthesis

Anatomical drawing of the first successful interbody fusion by B.H. Burns in 1933 [14] (with Permission from Elsevier).

[58]. In 1936, Jenkins tried to reduce the slip with traction and fusion [63]. Three decades later, Paul Harrington used his spinal instrumentation system to reduce severe spondylolisthesis [48].

Back Pain and Sciatica

Back pain has been known since the start of written history. Probably the first report of back pain and sciatica can be found in an ancient text, the so-called *Edwin Smith Surgical Papyrus* presumably written around 1550 B.C. [10].

The *Edwin Smith Surgical Papyrus* first described back pain (1550 B.C.)

In the industrialized countries, back pain today is the second most common reason for seeking medical care. Back pain accounts for 15 % of all sick leaves and is the most common cause of disability for persons under 45 years of age. However, in historical textbooks, only little information is available on backache. Waddell stated: "At first glance, backache appears to be a problem only since World War II. At second glance, we realize that not back pain but back related disability became a medical problem at the end of the last century" [118].

Not back pain but back related disability has dramatically increased in the last five decades

A Wrong Mixture of Fluids

The first descriptions of spinal pain, called sciatica, are also found in the Hippocratic texts *Predictions II* (*Praedictiones II*) [57].

Hippocratic texts first described sciatica

The *Predictions* are a collection of medical texts concerning especially symptoms, course, differential diagnosis and prognosis of a selection of different diseases. It is assumed that the famous Greek physician, Hippocrates of Cos (460 – 370 B.C.), the father of the Hippocratic oath, and his scholars contributed to this ancient medical textbook. Of note, Hippocrates did not differentiate between symptoms caused by spinal and femoral problems. Both entities were called "sciatic" at that time.

The outstanding and important Greek physician **Galen of Pergamon** (130 – 200 A.D.), who became physician to the Emperor Marcus Aurelius (121 – 180), described low back pain in his *Definition of Medicine* (*Definitiones Medicae*) similar to the Hippocratics [36]. Both the Hippocratics and Galen assumed a wrong

Initially "sciatica" described hip, buttocks, loin as well as leg pain

mixture of fluids to be the cause of such symptoms according to the so-called "fluid doctrine" of Hippocrates. Other ancient physicians had more or less the same explanation for the sciatic pain syndrome. During antiquity and the Middle Ages, this view persisted and the term "sciatic" served as a description for hip, buttocks, loins and leg pain.

The Italian physician **Domenico Felice Antonio Cotugno** (1736–1822) first differentiated sciatica from hip related pain in his pioneering study *De Ischiade Nervosa Commentarius* (*Commentary on Nervous Sciatica*) (1764). The nervous sciatica was called "*iscias nervosa Cotunni*" also known as the "*malum Cotunni*" or "Cotugno syndrome" (Fig. 6a) [21]. He was such a skilled clinical examiner he was able to divide his Cotugno syndrome into two entities:

- anterior "*iscias nervosa postica*"
- posterior "*iscias nervosa antica*"

Cotugno first differentiated nervous sciatica from musculoskeletal leg pain

The anterior "*iscias nervosa postica*" was described as pain radiating from the groin along the inside of the thigh and down the lower leg. The posterior "*iscias nervosa antica*" corresponded to pain radiating from the greater trochanter major along the outside of the thigh and down into the lower leg. Cotugno thereby became the first author to describe the lumboradicular syndrome.

Brown first assumed neural irritation to be a cause of back pain

However, the true cause of the nervous sciatica still remained unknown. He was still very close to the antique fluid doctrine. Cotugno is also known for his discovery of cerebrospinal fluid as outlined above, his discovery of aqueductus of the inner ear and his description of the typhoid ulcers. It was finally the English physician Brown of Glasgow in 1828 who first suggested that irritation of the nervous system could be responsible for back pain [13].

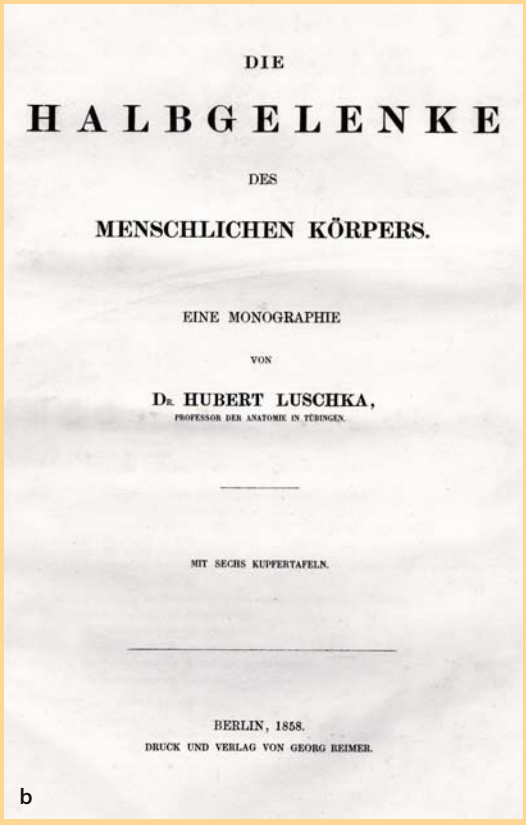
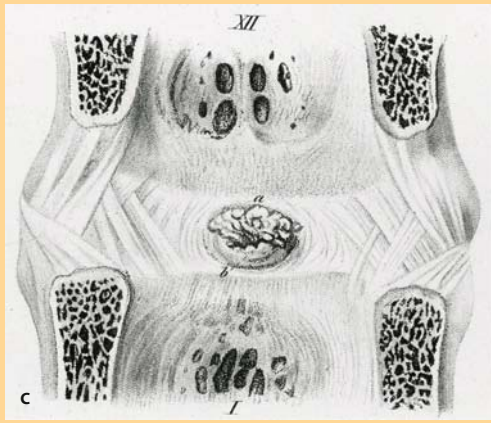
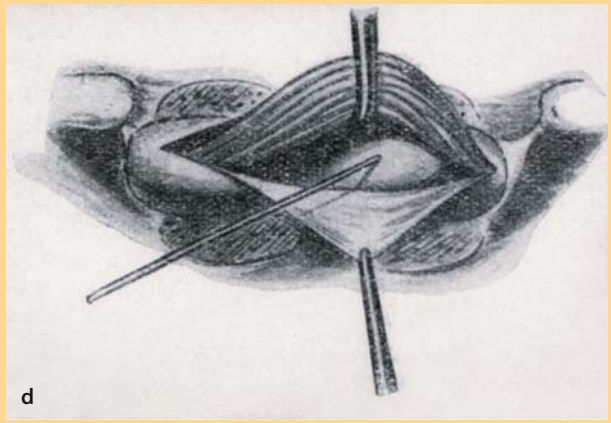


Figure 6. Back pain and sciatica

a Domenico Felice Antonio Cotugno (1736–1822). b *The Half Joints of the Human Body* published in 1858 by the German pathologist Hubert von Luschka (1820–1875).





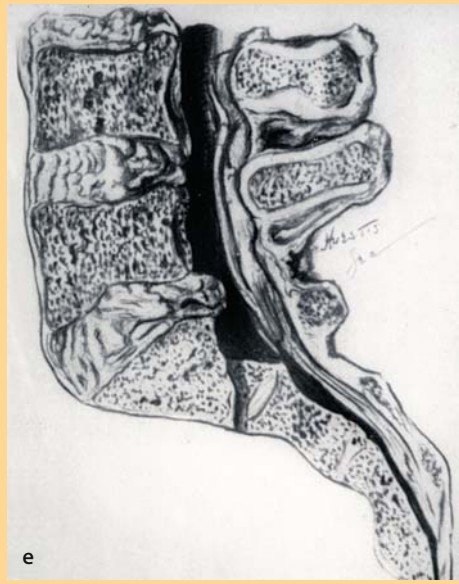


Figure 6. (*Cont.*)

c The illustration depicted in *The Half Joints of the Human Body* shows a nucleus protrusion of the intervertebral disc between the 12th thoracic and 1st lumbar vertebra. d The drawing shows removal of a so-called "extradural chondroma" depicted in the paper by Fedor Krause (1857–1937) and Heinrich O. Oppenheim (1858–1919) in 1908. e This drawing shows the concept of a disc compressing the cauda equina as seen by Joel E. Goldthwait (1867–1961).

Disc Herniation

Luschka (1820–1875) first described a protruded disc

After a brief report of protruded disc written by the great pathologist Virchow in 1858, the German pathologist **Hubert von Luschka** (1820–1875) published a detailed and concise description and illustration of a protruded disc in his epoch-making monograph *The Half Joints of the Human Body* (Fig. 6b) [75].

He supposed that these disc protrusions were caused by a tumor like cartilage outgrowth of the nucleus pulposus and called such protrusions anomalies of intervertebral discs (Fig. 6c). Notwithstanding Luschka's descriptions of a subligamentary and intraligamentary outgrowth of a cartilage-gelatinous mass from the nuclear material with a consecutive transligamentary burst, the effective origin of these disc protrusions and the clinical link to the sciatica were still unexplained for another 70 years. Luschka's scientific publications and anatomic textbooks became the gold standard of the time because of their clear presentation and excellent drawings.

Christian George Schmorl (1862–1932), Director of the Pathological Institute in Dresden, studied more than 5000 spine specimens. In 1928, he published two

cases of disc protrusion, which he interpreted as supplementary nuclei pulposi, remnants of the primitive chorda, respectively.

Andrea first proposed a degenerative origin of disc protrusion

Finally, in 1929, it was a disciple of Schmorl, **Rudolf Andrae**, who gave the accurate explanation for the disc protrusion. In his work *On Cartilage Node in the Posterior End of Intervertebral Disc Near by the Spinal Canal*, Andrae confirmed Schmorl's observations by describing 56 similar cases in 365 examined spines. Furthermore, he proposed that disc protrusion is based on a degenerative disruption of annular fibers which permits extrusion or sequestration of nuclear material. In addition he could exclude the theory of a neoplastic process as cause for disc protrusion [2]. Even though the pathophysiological mechanism was elucidated, there was no link to the clinical symptom of sciatica.

Krause and Oppenheim (1958 – 1919) first performed a discectomy

With the advent of neurotopic diagnosis using dermatomes at the end of the 19th century, specific operative intervention for the spine and spinal cord became possible. On 23 December 1908, the German surgeon **Fedor Krause** (1857 – 1937), who worked at the Augusta Hospital in Berlin together with the German neurologist **Heinrich O. Oppenheim** (1858 – 1919), was the first to operate on a disc prolapse in a patient who had suffered from severe sciatic pain for several years and had developed an **acute cauda equina syndrome** [90]. The operation (Fig. 6d) consisted of:

- laminectomy L2–L4
- splitting the dura
- mobilizing the cauda equina by a retractor
- exploring the operation field
- removing a small tumor mass

After the operation, the patient felt much better and the neurological problems disappeared. Following the theory of Luschka, Krause and Oppenheim supposed that this fibrocartilage mass was an enchondroma.

Goldthwait first proposed that sciatica is caused by a disc prolapse

In 1911, the American physician **Joel E. Goldthwait** (1866 – 1961) reported on a 39-year-old patient who initially suffered from an affection of the sacroiliac joint. The patient underwent inadequate manipulations and subsequently developed a cauda equina syndrome. Based on this case, he proposed that a prolapse of the intervertebral disc could be an explanation for many cases of lumbago, sciatica and paraplegia (Fig. 6e) [40]. At the same time, the physicians George S. Middleton (1853 – 1928) and John H. Teacher (1869 – 1930) reported a case of a laborer who had sustained a disabling injury during work while lifting a heavy object [74, 85]. The patient suffered from sciatica and paraplegia. The authors suggested that a disc rupture caused the severe clinical condition of that patient.

Disc Surgery

In 1929, the famous Walter E. Dandy (1886 – 1946), professor of neurosurgery at Johns Hopkins, discovered that nodules of discal origin could produce sciatica by compression and that their removal would cure pain. He published this hypothesis in the *Archives of Surgery* [25], but unfortunately little attention was paid to this article, because he called the protrusions and prolapses tumors. However, it was not until 1934 that the American neurosurgeon **William Jason Mixter** (1880 – 1958) and the orthopedic surgeon **Joseph Seaton Barr** (1901 – 1963), working at the Massachusetts General Hospital, established that the supposed neoplastic process was just a prolapse of the disc (Historical Case Study).

Mixter and Barr established the link between disc prolapse and sciatica

They also discovered the long missing link between sciatica and disc protrusion [86].

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NEW ENGLAND SURGICAL SOCIETY

RUPTURE OF THE INTERVERTEBRAL DISC WITH INVOLVEMENT OF THE SPINAL CANAL*

BY WILLIAM JASON MIXTER, M.D.,† AND JOSEPH S. BARR, M.D.†

DURING the last few years there has been a good deal written and a large amount of clinical work done stimulated by Schmorl's[1] investigation of the condition of the intervertebral disc as found at autopsy. His work will stand as the most complete, painstaking and authoritative that has ever been done in this condition. This work, however, is purely pathological and it now remains for the clinician to correlate it with the clinical findings and apply it for the relief of those patients who are disabled by the lesion.

FIG. 1. A normal intervertebral disc. Note cartilage plate, anterior and posterior longitudinal ligament, annulus fibrosus, and the semifluid nucleus pulposus which bears the superincumbent body weight and is retained in place under pressure by the annulus.

In the routine examination of spines from autopsy material he discovered that the intervertebral disc is often involved in pathological changes, the most common one being prolapse of the nucleus pulposus into an adjacent vertebral body. He found one or more such prolapses (Knorpel-knochen) in about thirty-eight per cent of the spines examined. He also discovered that in about fifteen per cent of the spines there were small posterior prolapses beneath the posterior longitudinal ligament, but concluded that they rarely, if ever, produced clinical symptoms. He attributed their presence to weakening of the annulus fibrosus by degenerative changes, with mild trauma as a second factor, producing fissures in the annulus and escape of the semifluid nuclear material.

On the other hand, for a number of years clinicians have been reporting cases of spinal cord pressure from intervertebral disc lesions.

*Read at the Annual Meeting of the New England Surgical Society, September 30, 1933, at Boston.

†Mixter, William Jason—Visiting Surgeon, Massachusetts General Hospital. Barr, Joseph S.—Orthopedic Surgeon to Out-Patients, Massachusetts General Hospital. For records and addresses of authors see "This Week's Issue," page 234.

In 1911 Goldthwait[2] reported a case of sciatica and paraplegia which he attributed to a posterior displacement of the intervertebral disc at the lumbosacral junction and suggested that such displacements might be the cause of many cases of lumbago, sciatica, etc. Middleton and Teacher[3] report a similar case confirmed at autopsy. Elsberg[4] in 1916 mentions chondroma of the vertebrae as causing compression of the cauda equina and states that Oppenheim has described a similar case. Mixter[5] in 1921 mentions a similar case and numerous other re-

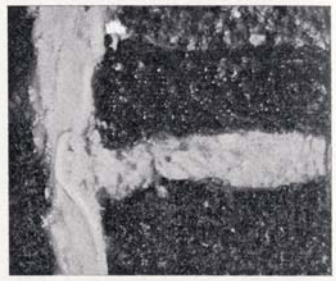
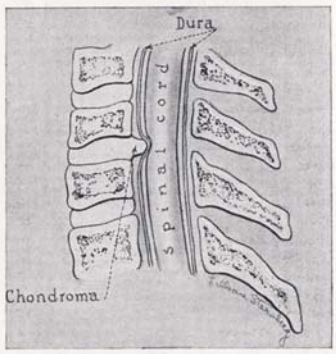


FIG. 2. Autopsy specimen. CASE 5. Note small posterior prolapse such as Schmorl describes.



(FIG. 17. Showing the usual location of a ventral vertebral disc chondroma. [Legend in *Surgery, Gynecology and Obstetrics*].)

FIG. 3. Illustration taken from article by Elsberg, showing "chondroma" arising from intervertebral disc. (Elsberg: S. G. & O.: 46: 10: 1928.

a

Historical Case Study

The following text represents a short extract of the milestone article "Rupture of the intervertebral disc with involvement of the spine canal" (a) (Massachusetts Medical Society, with permission): written by William Jason Mixter (b) and Joseph Seaton Barr (c) in 1934 [86]:

"The symptoms and signs of these so-called chondromata, which we believe in most instances represent rupture of the intervertebral disc, have been discussed at length by Elsberg and Stookey. The symptoms depend entirely on the location and size of the lesion. There is often a history of trauma not immediately related to the present condition. Numbness and tingling, anaesthesia, partial or complete loss of power of locomotion, are usually present. Bladder and rectal sphincter may be involved. The condition of the reflexes varies with the level of the lesion. If it is compressing the cauda equina the tendon reflexes may be absent; if higher, compressing the cord, the legs may be spastic and the reflexes exaggerated with positive Babinski sign. If the lesion is low in the spine, the physical examination may be suggestive of low back strain or sacro-iliac strain. X-ray examination may be entirely negative, but narrowing of the intervertebral space is often present and is of significance, as it ordinarily means escape of the nucleus pulposus, not necessarily but possibly into the spinal canal... Therefore we have developed certain ideas as to the operation when we suspect this lesion to be present.


b


c

Historical Case Study (*Cont.*)

Exposure of the spine and laminectomy are performed as usual except that the laminectomy is narrow and on the side where the lesion is suspected, for we believe that a ruptured disc is a weakened disc and the strength of the spine should be preserved as much as possible. The dura is opened and the spinal canal carefully explored, particular attention being given to the intervertebral discs in front of the cord and the intervertebral foramina. If the lesion is found in the midline it is approached by incising the dura over it as suggested by Elsberg. If it is lateral, the dura is closed and the dissection carried out to the side between the dura and the bone. If lesion is suspected in the intervertebral foramen it may be necessary to carry the removal of bone well out to the side, even taking in part of the pedicle. After removal the tumor is exposed. It frequently comes away without any dissection and if not, section across its base or removal with curette is bloodless. Though we have done it in only two cases, we believe that it may be advisable to slip bone chips in between the stumps of the laminae before closing the wound, in order to facilitate fusion. After removal of the tor piece of the disc one frequently finds an opening through which a probe may be passed into the nucleus pulposus... We conclude from this study: a that herniation of the nucleus pulposus into the spinal canal, or as we prefer to call it, rupture of the intervertebral disc, is a not uncommon cause of symptoms. That the lesion frequently has been mistaken for cartilaginous neoplasm arising from the intervertebral disc... That the treatment of this disease is surgical and that the results obtained are very satisfactory if compression has not been too prolonged."

This finding rapidly attracted surgeons and basic researchers to the intervertebral disc. The enthusiasm to solve back pain and sciatica surgically by disc excision started as Macnab called it "**the dynasty of disc**" [77]. The disc was thereafter made responsible for all kinds of back and leg pain and many treatment failures were the consequence.

Love developed the interlaminar "key hole" approach for discectomy

In the early days, the disc prolapse was removed by a full transdural approach with laminectomy. In 1939, **Grafton Love**, a surgeon at the Mayo Clinic, published a new method which he called "**key hole**" laminectomy, an intralaminar approach for disc prolapse removal, which preserved spinal stability. Therefore, his approach served also as a precursor to the microscopically assisted approach [73].

Lyman Smith introduced chemonucleolysis for disc prolapses

The American physician Lyman Smith developed a less invasive method for disc protrusions and reported his results in 1964 [109]. He injected chymopapain into the disc to shrink the disc protrusion. Although chemonucleolysis was effective, this method went out of fashion because of some cases of anaphylactic reaction and transverse myelitis.

Caspar and Williams introduced microdiscectomy

In 1975, Hijkata of Japan first reported on a percutaneous lumbar nucleotomy technique by a posterolateral approach [35]. In the late 1970s, the German neurosurgeon **Caspar** and the American neurosurgeon **Williams** introduced the use of the microscope for minimally invasive discectomy, which today has become the standard technique in many centers [17, 123].

In 1986, **P.W. Ascher** performed the first percutaneous laser decompression of intervertebral discs [14], but this technique never demonstrated clinical efficacy.

A further milestone in the treatment of degenerative disc disease was the development of an artificial disc, which allowed lumbar motion to be preserved. U. Fernström first implanted a rudimentary lumbar disc replacement consisting of a single steel ball in the late 1950s [34].

U. Fernström implanted the first lumbar disc prothesis

After several less promising developments of different designs, K. Schellnack and K. Büttner-Janz developed the SB Charite disc prothesis at the Charité (Hospital) in Berlin in the early 1980s [15]. Further developments of this prothesis type resulted in the first FDA approved total disc arthroplasty device.

The Facet Syndrome

It was the Belgian anatomist **Andreas Vesalius** (1514–1564), professor of anatomy at the University of Padua, who first correctly described the facet joint in his epoch-making anatomical textbook *De Humani Corporis Fabrica Libri Septi* in 1543 [116]. The American **Joel E. Goldthwait** (1867–1961), first surgeon-in-chief of the Orthopedic Department at the Massachusetts General Hospital, first realized that the facet joints also play an important role in low back pain [40]. Finally, in 1933, **R.K. Ghormley** is credited as having coined the term "**facet syndrome**" for back pain caused by altered facet joints [38]. This syndrome was re-popularized by Vert Mooney in 1976 [87], but debate continues about the clinical entity.

Ghormley coined the term "facet syndrome"

Spinal Stenosis

The first evidence of spinal stenosis can be found in Egyptian mummies. The first report of a spinal stenosis is attributed to the French surgeon **Antoine Portal** (1742–1832) in 1803. He observed at autopsy three specimens with narrowing of the spinal canal [93]. He was also able to relate the pathological findings to the typical clinical symptoms of spinal stenosis.

Portal made the first description of spinal stenosis in 1803

The Italian orthopedic surgeon **Vittori Putti** (1880–1940), one of the most outstanding European orthopedic surgeons of the first half of the 20th century, emphasized the relevance of anomalies or acquired degenerative alterations of

Vittorio Putti was the first to report the relevance of foraminal stenosis

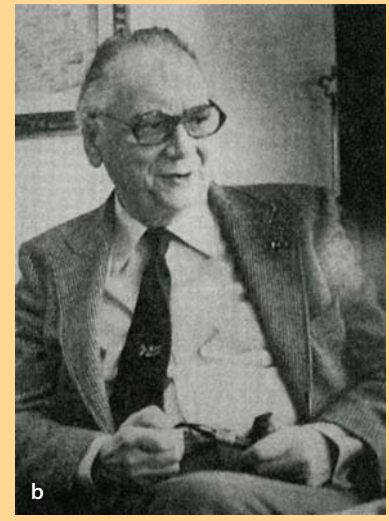


Figure 7. Spinal stenosis

a Vittorio Putti (1880–1940). **b** Henk Verbiest (1909–1997).

the intervertebral foramina and lateral recess, for causing sciatica by causing an entrapment of the existing root (Fig. 7a) [94]. In his article, published in *The Lancet* in 1927, Putti gained international attention and it was a further step in the understanding of the pathomechanism of sciatica in cases which are not caused by a slipped disc [95].

Henk Verbiest discovered the relevance of a narrow spinal canal

With the Dutch neurosurgeon Henk Verbiest (1909 – 1997), also known as the "pope of spinal stenosis", lumbar stenosis became a well-defined pathological entity (Fig. 7b) [4]. He introduced the concept of developmental stenosis, which is caused by an abnormally short midsagittal diameter of the spinal canal [114, 115].

Spinal Infections

Despite the advent of chemotherapy and improved surgical techniques, spinal infections are still a potentially life threatening disease even in the industrialized world. In the past, tuberculosis has played an important role as a cause of spinal deformities and was one of the most common "orthopedic" diseases all over the world.

Egyptian Mummies and Sir Percival Pott

Spinal tuberculosis is older than written history

Spinal tuberculosis is older than written history, because the first evidence of spinal tuberculosis was found in a skeleton from about 5000 B.C. [51]. Further evidence of spinal infection most likely caused by tuberculosis was found in Egyptian mummies dating from the Predynastic time, 3000 B.C. and earlier. A very good example of spinal tuberculosis was found in Neshparenhan, from the cache of 44 priests of Amun (21st Dynasty, 1100 B.C.) reported by Ruffer in 1910. The mummy reveals the typical features of Pott's disease with an acute angulation of the spine caused by the collapsed thoracic vertebral bodies and a psoas abscess (Fig. 8a) [103].

In the Hippocratic textbook *On Articulations*, extended descriptions about spinal deformities are in particular very similar to those of Pott's disease [50]. **Hippocrates of Cos** (460 – 375 B.C.) and his scholars have suggested treatment of patients by bench stretching and this became a very popular therapy for a long time. In 1896, the French orthopedic surgeon **Jean-Francois Calot** (1861 – 1944) tried to cure tuberculosis related spinal deformities by his "*redressment brusque*" (or "*redressment forcé*") based on the Hippocratic procedure (Fig. 8b) [16]. But after some brief enthusiasm, this treatment was abandoned because of various severe complications.

Pott recognized the link between tuberculosis, kyphosis and paraplegia

In 1779, the English surgeon **Sir Percival Pott** (1714 – 1788), author of classic monographs on head injuries and fractures, is credited as having recognized the tuberculous nature of this disease. He published his account of tuberculous paraplegia entitled *Remarks on that kind in palsy of the lower limbs, which is frequently found to accompany a curvature of the spine, and is supposed to be caused by it* (Fig. 8c) [94, 95]. The first association of paraplegia with kyphotic deformity was obviously made by the French surgeon **Jacques Dalechamps** (1513 – 1577) in 1570 [28].

Dalechamps first described the association of paraplegia and kyphotic deformity

Dalechamps still believed in the method of mechanical treatment of a "*spina luxata*" by performing extension and simultaneously sitting on the patient's hunchback as propagated by the famous Italian physician **Guido Guidi** (1500 – 1569) [42]. Although the tuberculous nature of spinal deformity had been surmised by Hippocrates and confirmed by Galen, it was Pott's classic description that finally brought the condition to clarity for the practitioner (Fig. 8d).

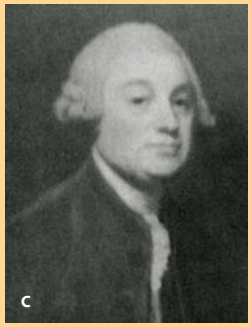


Figure 8. Spinal infection

a The Old Egyptian mummy Neshparenhan, a priest of Amun (circa 1100 B.C.), shows the typical features of Pott's disease: collapsed thoracic vertebral bodies with kyphotic angulation. **b** This painting illustrates the "*redressement forcé*" by the French orthopedic surgeon Jean-Francois Calot (1861 – 1944). **c** Sir Percival Pott (1714 – 1788). **d** The drawing of the so-called "carious spine" depicted in Pott's work in 1779.

He showed that there was not a luxation of vertebrae but an inflammatory abscess that compromises the spinal cord. **Pott's trias** was defined by three findings:

- paraplegia
- gibbus
- abscess

The true nature of "**spinal caries**" as tuberculous spondylitis was recognized by **Jacques-Mathieu Delpech** (1777 – 1832), murdered by a patient on whom he had performed a varicocele operation, and Carl Freiherr von Rokitansky (1804 – 1878) in 1842 [29, 100]. Finally, it was the famous German physician and bacteriologist **Robert Koch** (1843 – 1910), founder of modern experimental bacteriology

Robert Koch first discovered *Mycobacterium tuberculosis*

and Nobel prize winner in 1905, who succeeded in isolating and describing the germ of tuberculosis: *Mycobacterium tuberculosis*.

Treatment

Before the 19th century, treatment was just based on bed rest and/or cruel traction. It can be imagined what torture it was. Spinal frames and, later, plaster beds, plaster jackets and back supports came into almost universal use but without any proven benefit.

Despite the first experience of abscess drainage reported by Pott, this procedure seemed to be very dangerous because of the high death rate leading to controversies. With the advent of new surgical and supporting techniques in the late 19th century, more and more surgical approaches to the treatment of tuberculosis were developed. In 1909, the German surgeon **Fritz Lange** (1864 – 1952) tried to stabilize the tuberculous spine by fixing it up by means of celluloid bars and silk wire. Later he also used steel rods and wires [69].

Lange was a pioneer of internal spinal fixation

Albee performed the first successful spinal fusion

Fred Houdlette Albee (1876 – 1945), a great American orthopedic surgeon at the beginning of the 20th century and co-founder of the International Society of Orthopaedic Surgery and Traumatology (SICOT), first reported on a successful lumbar spinal fusion. Albee tried to stabilize the spine of a patient suffering from spinal tuberculosis. He first sagittally split the spinous processes, and then he laid a strip of autologous tibia between the two halves of them [1]. During this time, Albee was very interested in bone graft techniques and he therefore performed many bone graft experiments on dogs.

Albee's report was shortly followed by another account of lumbar spinal fusion written by his colleague **Russel A. Hibbs** (1869 – 1932), who became the surgeon-in-chief of the later New York Orthopedic Hospital in 1897. Hibbs also tried to produce a posterior fusion by using autologous bone graft.

Procedures were also developed which aimed to drain the abscess, e.g. abscess enucleation described in 1894 by the French orthopedic surgeon Victor Ménard [83]. However, none of these operative techniques produced satisfactory results.

Hodgson introduced radical debridement and anterior spinal fusion for tuberculosis

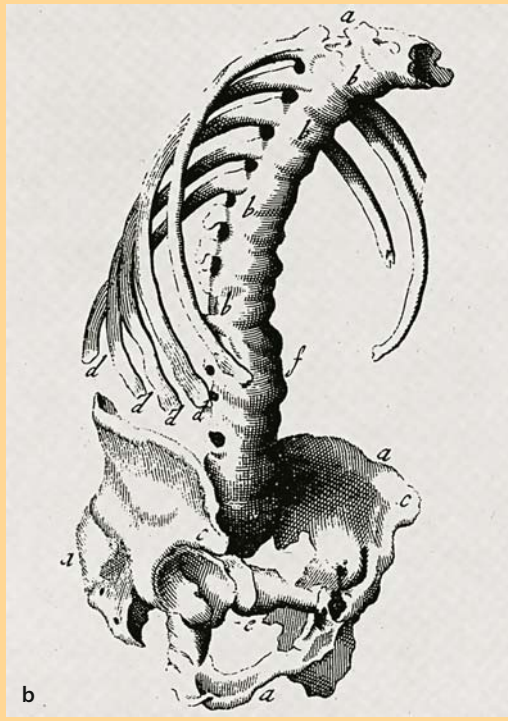
In the 1950s, **Arthur Ralph Hodgson** (1915 – 1993) (born in Uruguay to British parents) was a protagonist in what became known as the Hong Kong school of tuberculosis treatment [82]. Hodgson and his coworkers suggested a **new surgical technique** which consisted of:

- radical surgical debridement
- anterior spinal fusion with autologous bone-graft (rib, ilium) [58]
- chemotherapy

In the 1950s, although the first effective chemotherapies with streptomycin, isoniazid and paraamino-salicyclic acid were successful in the treatment of pulmonary tuberculosis, orthopedic surgeons were suspicious of the effectiveness for spinal tuberculosis [65, 88]. Based on the experience of the **Hong Kong school**, radical debridement, fusion and chemotherapy became the **gold standard** for cases with deformity and neurologic compromise [82].

Ankylosing Spondylitis

Ankylosing spondylitis is a highly heritable, common rheumatic condition, primarily affecting the axial skeleton. There is still no causative cure and for patients it remains a very disabling disease (Fig. 9a). The first evidence of ankylosing spondylitis was found in many Egyptian mummies ranging from 3000 B.C. up to the Roman



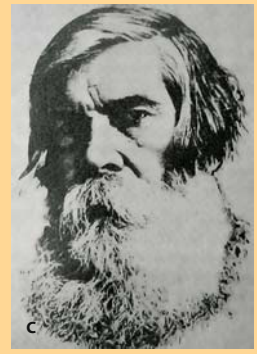


Figure 9. Ankylosing spondylitis

a Typical features of ankylosing spondylitis in the skeletal remains of a Late Medieval/Early Modern Times male 50 years of age from La Neuveville, Switzerland. **b** The peculiar skeleton as described by the Irish physician Bernard Connor (1666 – 1698). **c** Vladimir von Bechterew (1857 – 1927).

period [103]. A most likely case of ankylosing spondylitis is the one of Ramses II (1200 B.C.). He was one of the most powerful Egyptian kings ever and is remembered for his countless monuments, for example the temple in Abu Simbel [81].

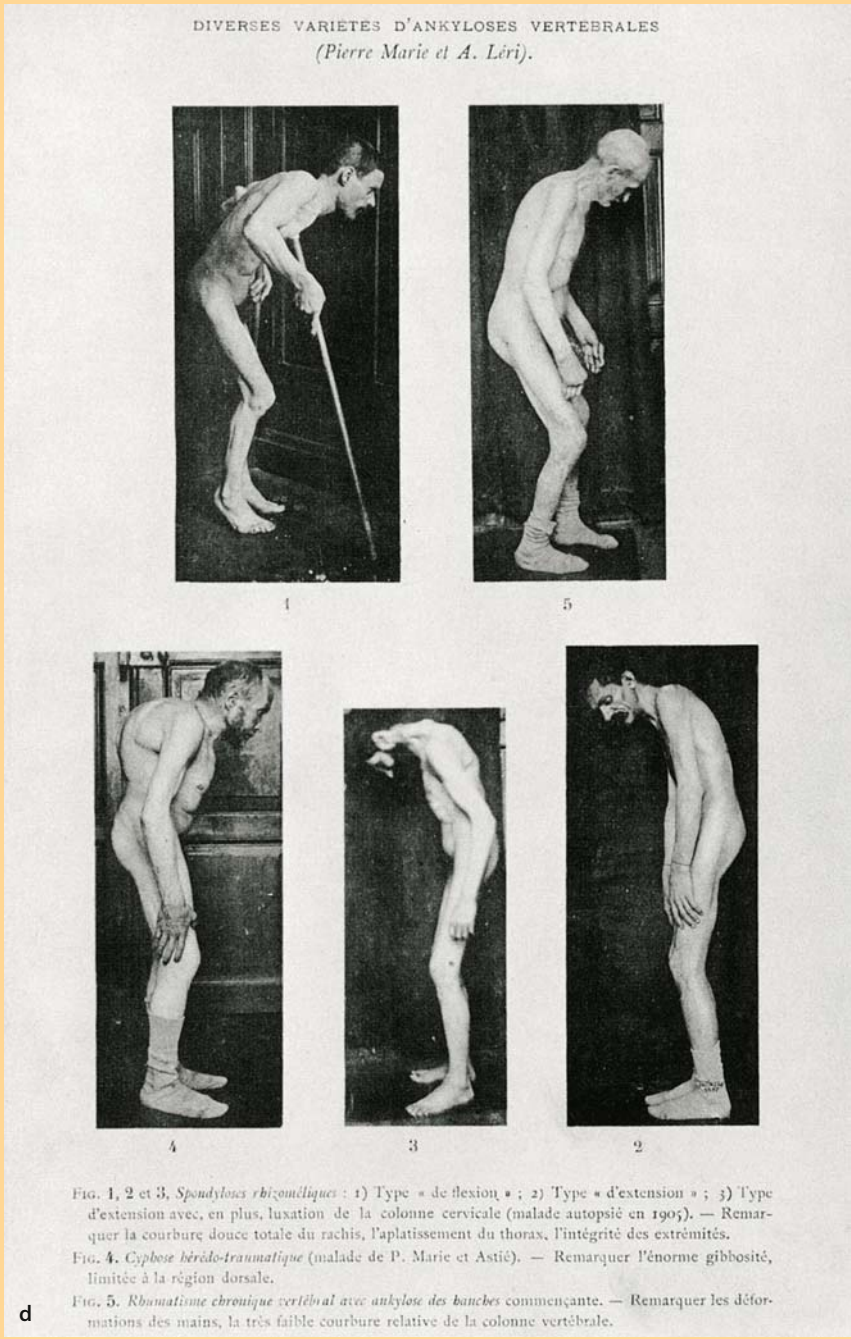
Discovery of a New Disease

Conner first described ankylosing spondylitis

The Irish physician **Bernard Connor** (1666 – 1698) gave a first accurate description of ankylosing spondylitis. He practiced for several years at the French Court during the regency of Louis XIV (1638 – 1715). He later became appointed physician to the Polish King John Sobieski in 1694. In 1693, he described an unusual skeleton consisting of a unified spine that was found in a local cemetery (Fig. 9b) [20]. He suggested that the deformity originated in utero as a consequence of pressure from abscess tumor in the womb or elsewhere.

Travers and Lyons both described cases of ankylosing spondylitis

First clinical reports of two putative cases of ankylosing spondylitis were both published in early issues of *The Lancet*. The first case, known as **Traver's case**, was reported by the St. Thomas Hospital (London) in 1824. The article deals with a young girl of good condition, who had suffered from a totally stiff spine caused by an ossification of the intervertebral disc as her treating physician **Benjamin Travers** (1783 – 1858) had assumed [112]. The second case report, published in 1832, was by **Philip Moyle John Lyons** (1804 – 1837) and dealt with a 36-year-old bricklayer who had been suffering from a severely stiffened immobilizing spine over several years with accompanying back and joint pain [76]. For the first time, the whole complex of ankylosing spondylitis was described fully and at length in


DIVERSES VARIÉTÉS D'ANKYLOSES VERTÉBRALES
(*Pierre Marie et A. Léri*).

1 5

4 3 2

Fig. 1, 2 et 3. *Spondyloses rhizoméliques* : 1) Type « de flexion » ; 2) Type « d'extension » ; 3) Type d'extension avec, en plus, luxation de la colonne cervicale (malade autopsié en 1905). — Remarquer la courbure douce totale du rachis, l'aplatissement du thorax, l'intégrité des extrémités.

Fig. 4. *Cyphose hérédo-traumatique* (malade de P. Marie et Astié). — Remarquer l'énorme gibbosité, limitée à la région dorsale.

Fig. 5. *Rhumatisme chronique vertébral avec ankylose des hanches* commençante. — Remarquer les déformations des mains, la très faible courbure relative de la colonne vertébrale.

d

Figure 9. (*Cont.*)

d The photographic plate from the treatise on ankylosing spondylitis written by the French neurologist Pierre Marie (1853–1940) published in 1906.

Bechterew popularized ankylosing spondylitis in Continental Europe

1877 by the English physician **Charles Hilton Fagge** (1838–1883), who worked at Guy's Hospital in London [33]. The Russian **Vladimir von Bechterew** (1857–1927), Professor of Neurology in St. Petersburg, was interested in ankylosing spondylitis (Fig. 9c). With his report on ankylosing spondylitis in 1893, he made it very popular in Europe [117]. That is why nowadays ankylosing spondy-

litis is often called "**Morbus Bechterew**". But he misconceived the etiology of ankylosing spondylitis, because he believed that the spinal stiffness was caused by a neurological disorder.

Finally, it was the German pathologist and bacteriologist **Eugen Fraenkel** (1853 – 1925), credited for his great work on pathology and differential diagnosis, who first introduced the name "ankylosing spondylitis" in 1904 [35].

The term "ankylosing spondylitis" was coined by Fraenkel

Another neurologist, **Pierre Marie** (1853 – 1940), professor in Paris, finally defined ankylosing spondylitis as an individual entity and proposed the name "*spondylose rhizomelique*". Solely by means of good clinical assessment (Fig. 9d) and without any technical devices, he was able to describe this disease as precisely and concisely as no one before him [80]. He also postulated that the etiology of ankylosing spondylitis is an osteopathy caused by infection or toxin, which finally leads to a hyperostotic process of the facet joints.

Spinal Injuries

Spinal injuries have been diagnosed and treated since antiquity and are still one of the most severe injuries which lead to handicap and disability. In the past, most of the patients with spinal cord injuries died after a short time because of a combination of pressure sores and urinary tract infection. Thanks to the good supportive techniques and rehabilitation developed since World War II, patients suffering from spinal cord injuries have better lifetime prognosis and living conditions.

Spinal injuries have been diagnosed and treated since antiquity

First Reports

Evidence of spinal fractures can be found in prehistory. The oldest known case of a spinal fracture in a presumably 34 000-year-old Early Stone Age (Upper Palaeolithic) skeleton from Stetten in Germany reveals a healed lumbar L3–L4 fracture [119].

A first description of spinal cord injuries is found in the *Edwin Smith Surgical Papyrus* [10]. The manuscript, written on papyrus, is dated to the 16th century B.C. (Historical Case Introduction). But it is widely believed that it is a copy of a much earlier work possibly 1 000 years older. In this text, collections of different instructions are found concerning for example a crushed cervical vertebra or cervical displacement of a vertebra.

The *Edwin Smith Papyrus* gives the first description of spinal injuries

Further evidence of spinal injuries is also given in the Hippocratic texts. According to the Hippocratic orthopedic textbook *On Articulations*, spinal injuries are classified into three different types [57] based on the direction of vertebrae displacement and the spine deformity:

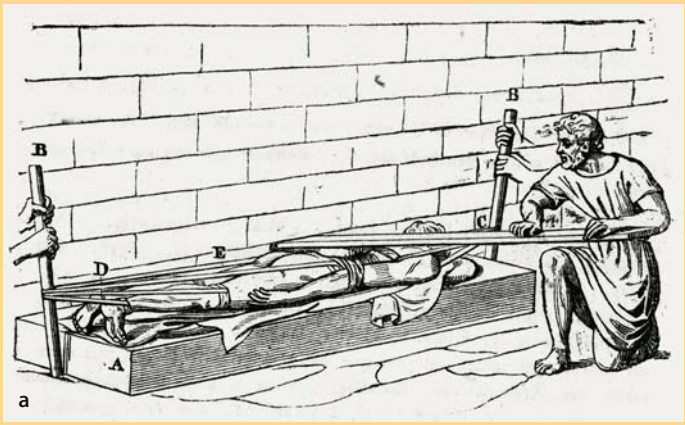
Hippocrates provided the first classification of spinal injuries

- anterior displacement
- posterior displacement
- injuries with no visible deformity

Each of these types is described with their prognosis.

Galen of Pergamon (130 – 200 A.D.) described spinal injuries in the same way as Hippocrates [36]. Additionally, **Galen** performed different experiments on spinal cord and spinal cord lesion in primates as outlined above, and he also made observations on patients with spinal injuries notably gladiators falling from chariots, perhaps the earliest recorded spinal injuries from road accidents. On this basis, Galen was able to diagnose the level of the injury by observing the paralyzed muscles and the area of sensational loss.

Galen already had a good knowledge of neurological topography



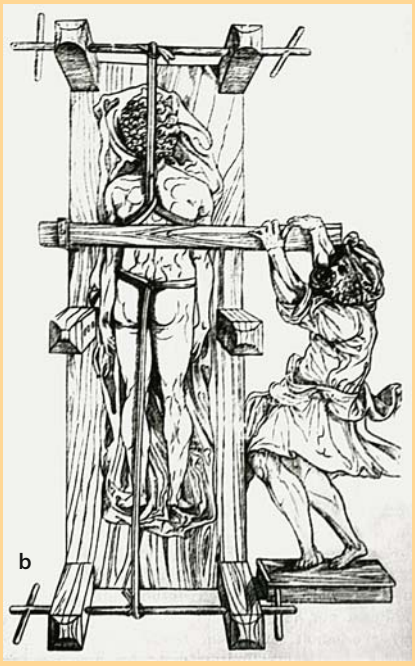


Figure 10. Spinal trauma

a Hippocates' Traction Table by E. Littré, who published the whole work of Hippocrates of Cos in the first half of the 19th century. **b** Hippocrates' Traction Table modified by Oribarius (325–400 A.D.) depicted in the surgical textbook of Guido Guidi (1500–1569). **c** Sir Ludwig Guttmann (1899–1985).

Spinal Injuries as a Socioeconomic Problem

The "railway spine" is a perfect example of the socioeconomic problems related to the spine

When the railways became popular in the first half of the 19th century, there were suddenly many patients claiming back pain and spinal injuries related to the use of the railway. Therefore, this phenomenon was called "railway spine". The medical textbook *On Railway and Other Injuries of the Nervous System* published by **John Erichsen** in 1866 was fully devoted to this subject [32].

There was great public and medical debate on railway spine and its enormous amount of compensation. This culminated for example in the medical advice of the Lancet Commission on the railway spine in 1862 [66]. At the end of the 19th century the "railway spine syndrome" fully disappeared as a real disease entity. The "**railway spine**" was epidemic between 1866 and 1880.

Harold Crowe coined the term "whiplash injury"

Another socioeconomic problem is the so-called whiplash injury, a traumatically caused cervical strain associated with rear-end collisions that leads to disability. The whiplash injury became epidemic with the increase in traffic accidents. The American surgeon **Harold Crowe** coined the term "**whiplash injury**" in 1928 [23].

Traction Table and Laminectomy

Traction tables were first used for fracture treatment

Since antiquity and through the whole of the Middle Ages, there were different kinds of treatment for spinal injuries available. The first one was the Hippocrates traction table, a popular device for treating every kind of spinal deformity, luxation and spinal injury (Fig. 10a). The Greek physician **Oribasius** (325 – 400 A.D.) improved Hippocrates' traction table (Fig. 10b) by adding a cross bar, which could be used as a lever for treatment of fracture dislocation [91]. This technique was still recommended at the end of the Middle Ages, for example by the famous Italian surgeon **Guido Guidi** (1508 – 1569) in 1544. Another approach to treating spinal fractures was introduced by the Greek physician **Paulus of Aegina** (625 – 690 A.D.), who was trained at the Alexandrian school and was the last of the great Byzantian physicians. He seems to have performed the first laminectomies in cases in which the posterior elements were fractured and pushed into the cord [92].

Paulus of Aegina first performed successful laminectomies for spinal injuries

The next historical description of a successful laminectomy was given by the American surgeon **Alban Gilpin Smith** (1788 – 1869) [109]. He performed surgery on a young man who had progressive paresis after falling off a horse 2 years before. Despite poor operating conditions, the patient recovered from the operation and experienced a return of sensation in the lower extremities.

During the Middle Ages, there were few descriptions on treatment of spinal injuries, and mostly physicians recommended conservative procedures. The Italian surgeon and anatomist **Guglielmo da Saliceto** (1210 – 1277) suggested in his work *On Surgery* (*Cyrurgia*) reducing cervical spine dislocation by manual traction on the extended head and then applying supportive braces and bandages [27]. The French surgeon **Guy de Chauliac** (1300 – 1368) is remembered as the father of surgery. He suggested in his profound work "*Surgery*" (*Ars Chirurgica*), which was based on Arabic physicians (such as Albucasis [936 – 1013] or Avicenna [981 – 1037]) and Galen, to "not labour to cure" in the case of spinal fracture [26].

The Advent of Internal Spinal Fixation

Ambroise Paré reintroduced surgery for spinal cord injuries

Ambroise Paré (1510 – 1590), the famous French surgeon, reintroduced the surgical approach to spinal cord injuries [79].

In 1646, **Guilhelmus Fabricus Hildanus** (1560 – 1634) described his attempts to replace fracture dislocation of the neck by means of clamping the soft tissues and spinous processes with large forceps [56]. In 1829, **Alban Gilpin Smith** (1788 – 1869) succeeded in performing a laminectomy. Other surgeons failed, because the patients died soon afterwards.

Smith performed the first successful laminectomy in 1829

Brodie propagated conservative treatment for spinal cord injuries

After that date, there was a great debate on the necessity of "decompressive laminectomy" which still continues today. In 1836, the famous **Sir Benjamin Brodie** (1783 – 1862), who is also famous for his description of the so-called "Brodie abscess", propagated in his *Pathological and Surgical Observations Relating to Injuries of the Spinal Cord* conservative treatment with bed rest and intermittent catheterization [12].

The treatment of spinal cord lesions was promoted by the special experience of army surgeons treating battle casualties. A further important step in the treatment of spinal injuries was the evolvement of anesthesia and aseptic surgery in the second half of the 19th century. The discovery of X-rays by **William Conrad Roentgen** (1853 – 1923) in 1895 and their clinical application since 1896 has also played an important role. During World War I, there was a big advance in neurological diagnosis and assessment, but not in the treatment of spinal injuries. Most patients died after a few weeks from urogenital infections. With the advent of

In the early 20th century most patients died shortly after a spinal cord injury

Wilkins introduced internal fixation for spinal fractures

supportative techniques at the end of the 19th century, the American surgeon W.F. Wilkins (1848–1935) was able to perform the first successful internal fixation of the spine. In 1887, he fixed a dislocated T12/L1 fracture by using a carbolized silver wire [112].

Four years later, the former Silesian obstetrician **Berthold Earnest Hadra** (1842–1903) used a similar technique in a case of a C6–C7 fracture of the cervical spine [43]. He just wired the spinous processes of C6 and C7 and reported that the result was successful. A great step forward in internal spine fixation was made when pedicle screw fixation was first introduced by **Raymond Roy-Camille** (1927–1994), appointed chief of orthopedics and traumatology at L'Hôpital de la Pitié-Salpétrière in 1963 [101, 102]. Another pioneer of spinal fixation is the Austrian surgeon **Friedrich Magerl**, who practiced at the Kantonspital in St. Gallen. He particularly contributed to the fixation techniques of the cervical spine (C1/2 screw fixation, lateral mass screw fixation, hock plate) and developed an external skeletal fixation system for the thoracolumbar spine which formed the basis for a new generation of angle-stable pedicular fixation systems [78].

Roy-Camille first introduced pedicle screw fixation

The first wheelchair for spinally injured patients was developed in 1930

The treatment of spinal injuries is not only based on surgical procedures, but also on non-operative care, which has significantly contributed to the increase in long-term survival. In 1930, the first wheelchair for patients suffering from spinal injury was developed and the focus of treatment slowly changed to rehabilitation, initiating spinal cord rehabilitation units.

Guttmann (1899–1985) first propagated rehabilitation for spinal cord injured patients

Since World War II and the early 1950s, major progress was made because of antibiotics and the great efforts of the neurosurgeon **Sir Ludwig Guttmann** (1899–1985), who was dedicated to the research and treatment of spinal cord injuries (Fig. 10c).

He propagated intensive rehabilitation and sports. He also wrote a profound and epoch-making textbook of spinal cord injuries in 1973 [44]. The death rate among spinal cord injured patients dramatically decreased as a result of these efforts. In World War I, 80 % of patients with spinal cord injuries died within the first 3 years, while in World War II this rate fell to about 7 %.

Recapitulation

Since the beginning of history, there has been evidence of spinal disorders and related treatments. The **Edwin Smith Surgical Papyrus**, dating from the 16th century B.C., reported different spinal disorders such as spinal injuries, backache and back sprain. Spinal tuberculosis is older than written history.

In antiquity, the famous **Hippocrates of Cos** (460–370 B.C.) and his scholars wrote on spinal disorders and described tuberculous spondylitis, spinal injuries and other spinal deformities. Hippocrates also invented a long-lasting device, the **Hippocratic Traction Table**, which was used for nearly every spinal deformity. The Greek physician **Galen of Pergamon** (130–200 A.D.) preserved the Hippocratic knowledge of medicine and spinal disorders, respectively. Additionally, he coined the word "scoliosis" and performed experiments on the spinal cord, which led to a better understanding of the nervous system.

At the end of antiquity, the Greek physician **Paulus of Aegina** (625–690 A.D.) first performed successful laminectomies.

The Middle Ages were practically devoid of any major advancement in the treatment of spinal disorders.

In the Renaissance, the studies of **Andreas Vesalius** (1514–1564), the father of modern anatomy, led to a better understanding of spinal anatomy based on the publication of his pioneering anatomical textbook in 1543. The famous French surgeon **Ambroise Paré** (1510–1590) developed the first scoliosis brace, which was in use for nearly 500 years.

In the Time of Enlightenment, **Sir Percival Pott's** (1714–1788) description showed the relation of tuberculosis, paraplegia and spinal deformities, which was an epoch-making discovery, because there was a high prevalence of tuberculosis at that time. **Domeni-**

co Cotugno (1736–1822) first described the difference between real sciatica and pain caused by the hip and related structures in 1764. Inspired by the philosophical ideas of that time, new therapeutic regimes for spine disorders were proposed and propagated, e.g. with the self-help book for parents *L'Orthopédie* written by **Nicholas Andry** (1658–1742) in 1741 or the foundation of the world's first orthopedic hospital by Jean André Venel (1740–1791) in 1780.

In the 19th century, general anesthesia started in 1846 with **William Morton**. Antiseptic principles were introduced by **John Lister** and others. **William Conrad Roentgen** discovered the diagnostic relevance of X-rays in 1895. The first successful laminectomy in modern times was performed by **Alban Gilpin Smith** (1788–1869) in 1829. An even better understanding of the pathology of different spinal diseases was gained, for example in scoliosis.

At the beginning of the 20th century, **William Jason Mixter** (1880–1958) and **Joseph Seaton Barr** (1901–1963) discovered the link between disc herniation and sciatica (1934). This discovery boosted the surgical treatment of sciatica but also led to overtreatment of this entity. Therefore, this period is called the "**dynasty of the intervertebral disc**". The Dutch neurosurgeon **Henk Verbiest** (1909–1997) clearly defined the clinical entity of a narrow spinal canal and popularized claudication symptoms in 1954. **Sir Ludwig Guttmann** (1899–1985) propagated a better treatment based on rehabilitation and sports activities for the spinally injured, which dramatically decreased mortality. Since the 1970s, the advent of new generation **spinal instrumentation devices** and **imaging modalities** has significantly improved the treatment of spinal disorders.

Appendix: History of spinal disorders

Time	Surgical procedures	Non-surgical procedures	Diagnostic modalities and other special facts
1550 B.C.			First description of spinal disorders in the *Edwin Smith Surgical Papyrus*
5th century B.C.		Hippocratic Traction Table	
7th century A.D.	First laminectomies performed by Paulus of Aegina		
1543			First accurate description of the spine by Vesalius
16th century		Ambroise Paré first developed a scoliosis brace	
1664			First picture of a scoliotic spine published by Hildanus
1741			Nicholas Andry published his textbook L'Orthopédie
1776			Domenico Cotugno first differentiated between a sciatica caused and a hip caused back pain
1779			Potts first recognized the link between tuberculosis, kyphosis, abscess and paraplegia
1780		Venel founded the world's first orthopedic hospital in Orbe, Switzerland	
1782			First description of spondylolisthesis by Herbiniaux
1803			Portal first described spinal stenosis
1828	First successful laminectomy in modern times performed by Alban Gilpin Smith		
1846			Anesthesia gained popularity after the public operation by Morton in Boston

Appendix: (*Cont.*)

Time	Surgical procedures	Non-surgical procedures	Diagnostic modalities and other special facts
1858			Concise description of disc protrusion by Luschka
1866–1880			Epidemic of the "railway spine" syndrome
1891	First internal fixation of a C6/C7 fracture by Hadra		
1895			Roentgen discovered X-rays
1898			First lumbar anesthesia by Bier
1900	First posterior fusion of C1/C2 by Pilcher		
1908	First report of a disc prolapse operation performed by Krause and Oppenheim		
1909	Stabilization of tuberculous spine by internal skeletal fixation performed by Lange		
1911	First lumbar spinal fusion performed by Albee		
1921			First description of Scheuermann's disease by Scheuermann
1928			First description of the "whiplash injury" by Crowe
1929			Discovery of penicillin by Fleming
1933			The term "facet syndrome" coined by Ghormley
1933	First anterior interbody fusion performed by Burns		
1934			Publication of the epoch-making article of Mixter and Barr about the pathophysiology of protruded disc and its clinical correlation
1935			Introduction of the measurement of Cobb by Lipmann
1944	First posterior interbody fusion performed by Briggs and Milligan		
1945		Milwaukee brace invented by Blount	
1956		Treatment of spinal tuberculosis with antibiotics suggested by Mukopadhaya	
1962	Harrington instrumentation		
1963	Introduction of pedicle screws by Roy-Camille		
1964	Chemonucleolysis invented by Lyman Smith		
1972			First CT image of the brain
1977	Introduction of external spinal fixation by Magerl		
1979			First MR image of the brain
1982	First artificial disc invented by Buttner and Shellnack		
1984	Cotrel-Dubousset instrumentation		

Key Articles

Breasted JH (1930) Edwin Smith Surgical Papyrus, in Facsimile and Hieroglyphic Transliteration and with Translation and Commentary, 2 Vols. Chicago: University of Chicago Oriental Publications
The Edwin Smith Surgical Papyrus edited by the American Egyptologist Henry Breasted encompasses different cases of spinal disorders. This medical text was probably written at the beginning of the New Kingdom of Ancient Egypt (around 1550 – 1500 B.C.). Therefore, these descriptions represent the earliest written witnesses of spinal disorders and its treatment in history.

Luschka H (1858) Die Halbgelenke des menschlichen Körpers. Eine Monographie. Berlin: Reimer
The Half Joints of the Human Body is a very important anatomical monograph written by the German pathologist Hubert von Luschka (1820 – 1875) in 1858.
In this monograph, there are detailed and concise descriptions and illustrations of protruded discs [64]. Luschka supposed that the disc protrusions were caused by a tumor like cartilage outgrowth of the nucleus pulposus and called such protrusions anomalies of intervertebral discs.

Cotunnius D (1764) De ischiade nervosa commentarius. Naples: Typographia Simoniana
Another milestone of spinal surgery is represented by *De ischiade nervosa commentaries* written by the Italian physician Domenico Felice Antonio Cotugno (1736 – 1822) in 1764.
This work encompasses for the first time in medical history a concise and precise differentiation of hip or lower back derived back pain. Cotugno's descriptions are very accurate and so he was already able to distinguish a L5 radiculopathy from a L3/4 radiculopathy. Thus, he became the first to describe the lumboradicular syndrome.

Pott P (1779) Remarks on that kind of the lower limbs, which is frequently found to accompany a curvature of the spine, and is supposed to be caused by it. London: J. Johnson
This paper represents a further remarkable text on spinal surgery in respect to history. This medical text was published by the English surgeon Sir Percival Pott (1714 – 1788) in 1779. In this work, he described the tuberculous paraplegia and considered the tuberculous nature of the disease.

Mixter WJ, Barr JS (1934) Rupture of the intervertebral disc with involvement of the spinal canal. N Engl J Med 211:210 – 215
This landmark paper is a key to the pathophysiology of the lumbar disc protrusion and the correlation to sciatica.

Harrington PR (1962) Treatment of scoliosis and internal fixation by spine instrumentation. J Bone Jt Surg Am 44:591 – 610
Paul R. Harrington (1911 – 1980) has popularized spinal internal instrumentation for scoliosis. In this article, the Harrington spinal instrumentation system, a method of spine curvature correction by means of a metal system of hooks and rods, is for the first time extensively described. Harrington developed this surgical procedure after a poliomyelitis epidemic, where thousands of people were affected. This article is a milestone in spinal surgery because of the introduction of internal spinal instrumentation for deformity surgery.

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